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WIND-TUNNEL INVESTIGATION OF SHIELDED HORN BALANCES

AND TABS ON A 0.7-SCALE MODEL OF XF6F

VERTICAL TAIL SURFACE

By John G. Lowry, James A. Maloney,
and I. Elizabeth Garner

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

ADVANCE CONFIDENTIAL REPORT

WIND-TUNNEL INVESTIGATION OF SHIELDED HORN BALANCES
AND TABS ON A 0.7-SCALE MODEL OF XF6F
VERTICAL TAIL SURFACE

By John G. Lowry, James A. Maloney,
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SUMMARY

An investigation was made in the LMAL 7- by 10-foot tunnel of a 0.7-scale model of the vertical tail surface of the Grumman XF6F airplane. The model was also utilized for a more general investigation of the effect on the hinge-moment characteristics of shielded horns of different chords, spans, and nose shapes and of trimming tabs of two nose shapes. An unshielded horn was tested for comparison with the shielded horn, and the results of the comparison are given.

Analysis of the data showed that for most tail surfaces it will be impossible to obtain by means of shielded horns a closely balanced surface and keep the rate of change of hinge-moment coefficient with angle of attack near zero without the addition of some other balancing device. With shielded horns, the rate of change of hinge-moment coefficient with rudder deflection could be reduced to about 50 percent of the unbalanced value without obtaining a positive value of the rate of change with angle of attack large enough to give steady oscillations of the airplane with free rudder. Pressure-distribution and tuft tests were made of the flow over horns of two nose shapes. Lower peak pressures and consequently higher critical speeds were obtained for the medium-nose horn than for the blunt-nose horn. The tests of the two trimming tabs showed that the shape of the tab nose made very little difference in the results.

INTRODUCTION

Tests were made in the LMAL 7- by 10-foot tunnel of a 0.7-scale model of the XF6F vertical tail surface. These tests were undertaken to obtain data for use in the design of shielded horns in general and to obtain data useful for the XF6F vertical tail in particular. Additional tests were made to determine tab characteristics for two different tabs and flow characteristics over several of the shielded horns.

The various shielded horn balances tested included models of the original horn on the XF6F airplane and of shielded horns of four chords, each of which was tested with two different spans and nose shapes. The variation in horn size covers the range from no balance to over-balance. Flow characteristics were determined by tuft tests of two of the smaller horns and pressure-distribution tests of two of the larger horns. The pressure-distribution data show the local velocity distribution of the two nose shapes tested. For convenience, the term "shielded horn" will generally be referred to as "horn," followed by a designation to indicate the horn size and nose shape.

Tests were made of an unshielded horn balance to determine whether any correlation between shielded and unshielded horns was possible. These tests were also the logical extension of those of the short-span shielded horns.

Characteristics of the tab were determined in order to have information useful in the design of any balancing or unbalancing device that uses tabs, as well as to have the characteristics of the particular trimming tabs tested. A round-nose tab of the same plan form and size as the original tab was tested to determine the variations in characteristics, if any, from the original tab. The round-nose tab represented the type of tab usually used on wind-tunnel models. Both tabs were tested sealed and unsealed.

APPARATUS AND METHODS

The model was mounted vertically in the LMAL 7- by 10-foot tunnel with one end adjacent to the floor of the

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tunnel, which acted as a reflection plane. (See figs. 1 and 2.) The model was supported entirely by the balance frame (fig. 1) with a small clearance at the tunnel floor in order that all the forces and moments acting on the model could be measured. Provisions were made for changing the angle of attack of the model and the deflection of the rudder while the tunnel was in operation. The hinge moments of the moving surfaces were measured by means of electrical strain gages mounted within the model, and the rudder deflections were measured by an electrical position indicator attached to the rudder and mounted within the surface. For the pressure-distribution tests, the pressures were recorded photographically from a multiple-tube manometer located outside the tunnel.

The 0.7-scale model of the XF6F vertical tail surface was built by the National Advisory Committee for Aeronautics and conformed to the dimensions of figure 3. The airfoil sections used (fig. 3) were modified NACA 16-series airfoils with the portion rearward of the rudder hinge line faired to a flat contour. The tip contour was changed somewhat from the shape used on the airplane in that it was built with semicircular sections through the tip to allow for changing the horn shape and size easily. The trailing edges of the cover plates were 0.61 inch ahead of the rudder hinge line from the root section to station 47.93 and tapered from 0.61 inch at station 47.93 to 0.35 inch at the tip. The rudder was sealed with a flexible seal for most of the tests; the hinges, however, were not sealed. Some geometric characteristics of the model are given in the table in figure 3.

Several different arrangements of shielded horn balances were made for the model and are shown in figure 4. Horn 2-a (fig. 4(i)) represents the horn on the XF6F airplane with the exception of the tip fairing. The other shielded horns were tested with two different nose shapes. The blunt-nose horns are of airfoil contour from the hinge line to the point of tangency with the leading-edge radius. The medium nose shapes were made to the ordinates given in table I. The variations tested included horns of four chords and two spans and cover the range from no balance, plain rudder, to a condition of overbalance. The gap between the horn nose and fin extension was similar to the one on the airplane for horn 2-a and was maintained for all other horn arrangements. The gap between the inboard end of the horn

and fin was 0.22 inch, which corresponds to the gap on the XF6F vertical tail.

The unshielded horn tested is shown in figure 5 and was made to the same span as horns 1, 2, 3, and 7. The shape of the horn is the same as the airfoil tip shape and has the same gap between the horn and fin as the shielded horns.

The plan form and geometric characteristics of the tabs tested are given in figure 3 and the sections of the tabs are given in figure 6. The original tab represents the tab on the XF6F rudder. The leakage through the piano hinge was simulated by a piece of gauze. The round-nose tab was constructed as shown in figure 6 and had provisions for sealing. Both tabs were sealed with a flexible seal for some tests.

Horns 8-a and 8-b were modified for pressure-distribution tests by placing a row of orifices 5.97 inches from the inboard end of the horn, as shown in figure 7. The chordwise locations of the orifices are given in figure 7 and are the same for both horns, except that orifice 1 on horn 8-a was eliminated from horn 8-b. These orifices were connected to copper tubes that were in turn connected to leads from the manometer. The copper tubes were kept within the model until they were a few inches from the tunnel floor. When pressure-distribution tests were made, time was allowed for conditions in the tunnel and for the manometer to become stable before the pressures were photographed.

A dynamic pressure of 16.37 pounds per square foot, which corresponds to a velocity of about 80 miles per hour and to a test Reynolds number of about 2,300,000 based on the model mean chord of 3.16 feet, was maintained for nearly all tests. In some cases it was not possible to maintain the dynamic pressure at 16.37 pounds per square foot because of the high drag at large angles of attack and rudder deflections, for which the dynamic pressure was decreased and corresponding corrections were made in the computations.

RESULTS AND DISCUSSION

Coefficients and Symbols

The coefficients and symbols used in the report are defined as follows:

C_L	lift coefficient $(L/q_o S)$
C_D	drag coefficient $(D/q_o S)$
C_{Di}	induced-drag coefficient
C_m	pitching-moment coefficient $(M/q_o S c)$
C_h	hinge-moment coefficient $(H/q_o b \bar{c}^2)$
P	pressure coefficient $[(p-p_o)/q_o]$
L	lift of model
D	drag of model
M	pitching moment about mounting-axis center line
H	moment about control-surface hinge line
S	area
q_o	dynamic pressure of free air stream $\left(\frac{1}{2} \rho V_o^2\right)$
b	span
c	chord (for movable surfaces, measured from hinge line to trailing edge)
c'	mean chord
\bar{c}	root-mean-square chord
B	balance coefficient $\left(\sqrt{S_H c_H' / S_r c_r'}\right)$
p	static pressure at an orifice
p_o	static pressure of free air stream
ρ	mass density of air

V local velocity at a point

V_o free-stream velocity

α angle of attack of model

δ control-surface deflection relative to surface to which control surface is hinged, positive when trailing edge is moved left

$$C_{h\alpha} = \left(\frac{\partial C_h}{\partial \alpha} \right)_{\delta_r, \delta_t}$$

$$C_{h\delta} = \left(\frac{\partial C_h}{\partial \delta} \right)_{\alpha, \delta}$$

$$C_{L\alpha} = \left(\frac{\partial C_L}{\partial \alpha} \right)_{\delta_r, \delta_t}$$

$$C_{L\delta} = \left(\frac{\partial C_L}{\partial \delta} \right)_{\alpha, \delta}$$

$\Delta C_{h\alpha}$ $C_{h\alpha}$ of rudder with shielded horn - $C_{h\alpha}$ of plain rudder

$\Delta C_{h_r \delta_r}$ $C_{h_r \delta_r}$ of rudder with shielded horn - $C_{h_r \delta_r}$ of plain rudder

All parameters have an angle range of about $\pm 5^\circ$.

Subscripts:

r rudder

t tab

H horn

Symbols or coefficients without subscript refer to complete vertical tail surface.

Corrections

All the coefficients have been corrected for the effect of the jet boundaries. No corrections have been made for the effect of gap between the root section and the floor or the leakage around the support strut. The over-all corrections applied (by addition) to the tunnel data are as follows:

$$\Delta\alpha = 1.53C_{L_{corrected}} \quad (\text{in deg})$$

$$\Delta C_L = -0.012C_L$$

$$\Delta C_{D_i} = 0.0233C_L^2$$

$$\Delta C_m = 0.00447C_L$$

$$\Delta C_h = kC_L$$

where

Horn	k
None	0.0085
1	.0083
2	.0080
3	.0075
4	.0082
5	.0077
6	.0067
7	.0078
8	.0072
Unshielded	.0065

The results of the pressure-distribution tests have not been corrected as described.

The results of this investigation represent the aerodynamic characteristics of a semispan tail surface and will have to be changed to the proper aspect ratio if applied to a vertical tail surface. The effect of the horn and of tab deflection on the hinge-moment characteristics should, however, be applicable to any control surface of similar plan form without correction for aspect ratio. The absolute values of hinge-moment, lift, and drag coefficients should, however, be corrected if applied to a vertical tail surface for the purpose of estimating airplane characteristics.

Plain Rudder

Tests were made of the plain rudder to obtain a basis for the effect of the horns on the hinge-moment characteristics. These tests included tests of the rudder unsealed (fig. 8) and tests of the rudder sealed (fig. 9). Sealing the rudder had no effect on the lift characteristics but did change the value of $C_{h\delta_r}$ from -0.0084 to -0.0077.

Tests were made of the sealed rudder to determine the effect of fixing the transition at or near the leading edge of the surface (fig. 10). The transition was fixed by roughening the first 5 percent of the fin with No. 60 emery dust. The main effects of the roughness were to decrease slightly the slope of the lift curve $C_{L\alpha}$, to decrease the effectiveness of the rudder $C_{L\delta_r}$, and to decrease the maximum lift coefficient. The hinge-moment characteristics were not appreciably affected by roughening the leading edges of the fin.

Shielded Horns

Original horn.- The results of the tests of the original horn (horn 2-a) are presented in figure 11. This horn represented the horn on the XF6F vertical tail except for the shape through the tip. A few tests were made of a horn of the same size and nose shape except that the radius on the outboard leading edge was eliminated, with the result that this horn had the same plan form as the other horns tested. The data of this modification were not noticeably different from the data of horn 2-a and are therefore not presented.

Modified horns.- The hinge-moment characteristics (fig. 12) indicate that the addition of the horn results in a positive increase in the slope of the hinge-moment-coefficient curves for both α and δ_r throughout the unstalled range of α or δ_r . The curves of hinge-moment coefficient against rudder deflection show no discontinuity when the horn unports, that is, when the chord line of the horn projects beyond the surface of the fin. Comparison of increments of hinge-moment coefficient for any of the various horns shows that the increment is linear with rudder deflection or angle of

attack through the unstalled range. A comparison of the individual curves of figures 12(a) and 12(b) indicates that, although the use of some of the larger horns gives a large positive increase in $C_{hr\delta_r}$ over the small deflection range, the values of C_{hr} for these horns in the stalled range with large rudder deflection are increased.

In order to obtain a more comprehensive comparison of the shielded horns, the values of $\Delta C_{h\alpha}$ and $\Delta C_{hr\delta_r}$ were plotted against balance coefficient B of reference 1 in figure 13. The curves for the unshielded horns of reference 1 have been included for comparison. The data of figure 13 indicate that the values of $\Delta C_{h\alpha}$ and $\Delta C_{hr\delta_r}$ increase evenly with balance coefficient. The values of $\Delta C_{h\alpha}$ are independent of nose shape for a given value of B , but the values of $\Delta C_{hr\delta_r}$ are larger for the blunt nose than for the medium nose. The values of $\Delta C_{h\alpha}$ for the shielded horns are about 60 percent as great as for the unshielded horns in the range tested. The values of $\Delta C_{hr\delta_r}$ are less for the shielded horns for values of B below 0.35 but are higher than for the unshielded horns for values of B greater than 0.35.

A comparison of the lift characteristics for several arrangements of shielded horns (table II) indicates that there are only small changes in $C_{L\alpha}$ and $C_{L\delta_r}$ with horn shape or size. A large part of the variations shown may be the result of experimental error. The test data are not presented for the lift characteristics, which were very similar to the characteristics of the plain rudder. The nose shape of the horn had little effect on the value of $C_{L\delta_r}$ taken from deflections of $\pm 10^\circ$, but the medium nose in some cases gave a value of $C_{L\delta_r}$ based on deflections of $\pm 4^\circ$ about 5 to 10 percent less than those based on deflections of $\pm 10^\circ$. This effect was, however, limited to small deflections and did not affect the values of C_L at large values of δ_r .

Complete force tests were made of the XF6F vertical tail with horns 8-a and 8-b to determine the characteristics of a horn giving closer balance than horn 2-a. The results of these tests are presented in figures 14 and 15 and can be used to estimate the hinge-moment-coefficient curves for other horns by interpolating between the values for horn 8 and horn 2 and/or the plain rudder from the curves of figure 13.

Dynamic-stability estimates.- Closely balanced rudders are desirable, but balancing the XF6F rudder with a shielded horn leads to a positive value of C_{h_a} . The oscillatory characteristics of the XF6F airplane were estimated by the method of reference 2. It was assumed that the rudder had no moment of inertia and that the rudder was mass-balanced, although the rudder was known to have some mass overbalance on the airplane. The assumption of no inertia tends to overestimate the stabilizing effect on the oscillations whereas the assumption that the rudder is mass-balanced tends to underestimate the effect. (See reference 2.) It appears that all of the horns except 6 and 8 would fall in the completely damped region; all of the horns except 3, 6, and 8 could be further balanced by use of balancing tabs without going out of the region of complete damping.

From reference 2 it appears that if the rudder is to be closely balanced - that is, $C_{h_r \delta_r}$ approaches zero -

C_{h_a} must be held near zero if complete damping is to be obtained. A comparison of the values of ΔC_{h_a} and $\Delta C_{h_r \delta_r}$ at a constant value of B from figure 13

indicates that ΔC_{h_a} increases about seven-tenths as fast as $\Delta C_{h_r \delta_r}$; thus, if complete balance is to be

obtained by use of shielded horn alone, the unbalanced control must have the ratio $C_{h_a}/C_{h_r \delta_r} = 0.7$. Inasmuch

as this ratio appears to give a value of C_{h_a} higher than found with most control surfaces, some other type of balance is required to reduce $C_{h_r \delta_r}$ to give the ratio

desired. Several types of balancing device may be used

including internal balances, overhang, or balancing tabs; however, any balancing device that reduces $C_{h\alpha}$ about the same amount as $C_{h_r\delta_r}$ cannot be used. The results

of this study indicated that for the XF6F vertical tail surface it is possible to reduce $C_{h_r\delta_r}$ to about

50 percent of the unbalanced value without obtaining positive values of $C_{h\alpha}$ large enough to give steady

oscillations.

Tuft study.— Figures 16 and 17 give some of the results of the tuft study of horns 2-c and 2-d, respectively. These photographs show the flow characteristics over the two horns at several rudder deflections and two angles of attack. The results indicate little difference between the two nose shapes, blunt-nose horn 2-c and medium-nose horn 2-d, except at zero rudder deflection and zero angle of attack, for which the medium nose shows unsteady flow over the leading edge of the horn. The photograph of horn 2-c with $\alpha = 0^\circ$ and $\delta_r = 0^\circ$ is not shown, as the tufts all lay straight back. Figure 18 shows the flow over the tip of the tail surface at several angles of attack with the rudder neutral.

Pressure distribution.— The pressure-distribution diagrams (figs. 19 to 28) give the pressures over the upper and lower surfaces of horns 8-a and 8-b for several angles of attack and rudder deflections. The pressures are plotted normal to the chord line of the rudder and horn. Although taken at only one spanwise location, these pressure curves should be useful in the design of shielded horns, as they give a general distribution of the loads over the horn.

The curves indicate that, in general, the medium-nose shielded horn 8-b gave lower peak pressures and consequently higher critical speeds than the blunt-nose horn 8-a. Additional pressure data were taken that showed a considerable hysteresis in stall characteristics, but the force tests failed to show this effect in the rudder hinge moments. This effect might result because the rudder shows a hysteresis that compensates for the change in flow over the horn. No results that show this effect are presented because pressure tests of the rudder are not available and the over-all hinge-moment coefficients were not changed.

The pressure plots can also be used to determine the local velocity ratio over the shielded horn by means of the equation

$$V/V_0 = \sqrt{1 - P}$$

where

V local velocity at a point

V_0 free-stream velocity

By using the curve of figure 22 of reference 3 and the peak pressures found from the pressure-distribution tests of horns 8-a and 8-b, the curves of figure 29 were estimated. Although the test points shown in figure 22 of reference 3 do not fall on the curve, later tests of symmetrical airfoils show good agreement with the curve. The curves of figure 29 show that the reduction of critical Mach number with rudder deflection is much less for the medium-nose than for the blunt-nose horn, as would be expected. Inasmuch as no pressure measurements were made over the complete tail surface, it is impossible to determine whether these pressures are critical for the tail assembly or for the horn only. Figure 29 does, however, indicate the critical speeds of the various horns plotted against rudder deflection and may be useful in determining the horn nose shape.

Unshielded Horn

The results of the tests of the unshielded horn on the model of the XF6F vertical tail surface (fig. 30) show irregularities in the hinge-moment-coefficient curves not found in the curves for shielded horns (figs. 11 and 14). The values of $\Delta C_{hr\delta_r}$ and $\Delta C_{h\alpha}$

for the unshielded horn are plotted in figure 13 and agree quite well with the unshielded horns of reference 1. The value of $\Delta C_{hr\delta_r}$ falls within the range of B for which there is little difference between the shielded and unshielded horns and therefore agrees quite well with the medium-nose shielded horns.

The unshielded horn tested was expected to be too large for the XF6F vertical tail but was tested solely to obtain a comparison between shielded and unshielded

horns of the same span. If an unshielded horn were used, it would have to be considerably smaller and would have to have an auxiliary balance device to reduce the negative value of $C_{hr\delta_r}$.

Tab Characteristics

The results of the tests of the original tab are presented in figures 31 to 36 and of the round-nose tab, in figures 37 to 44. The original tab is less effective in the negative rudder deflection range when the tab is deflected negatively than when the tab is deflected positively or when the round-nose tab is used. With both the original and the round-nose tabs, the tab and rudder hinge-moment coefficients indicate that, in the high negative rudder and tab deflection range and with α near 25° , the tab stalls and shows little change in hinge-moment coefficient C_{ht} with rudder deflection and in rudder hinge-moment coefficient C_{hr} with tab deflection. As δ_t is reduced to zero, the condition eases and is improved when the tab is deflected positively. In fact, when δ_t is 20° , there is a very large increase in C_{ht} as the rudder is deflected from -20° to -32° .

Both the original and the round-nose tabs were sealed for some tests to determine the effect of the seal. Sealing the original tab appears to have changed $(\partial C_{hr} / \partial \delta_t)_{\alpha, \delta_r}$ from -0.020 to about -0.025 and $C_{ht\delta_t}$ from -0.0070 to -0.0065. Sealing the round-nose tab changed $(\partial C_{hr} / \partial \delta_t)_{\alpha, \delta_r}$ from -0.025 to about -0.032 and $C_{ht\delta_t}$ from -0.0055 to -0.0045.

The data presented for the two trimming tabs are applicable to a rudder with any of the horn modifications tested. These data should be useful in the design of any tab device to reduce the amount of overbalance or to be used as an unbalancing tab. The data were taken on the rudder with no horn in order that the tab effects would be more easily distinguished, as the hinge-moment-coefficient curves for the unbalanced rudder are, in general, more regular.

CONCLUSIONS

An investigation was made in the LMAL 7- by 10-foot tunnel of a 0.7-scale model of the vertical tail surface of the Grumman XF6F airplane. Tests to determine the effect on the hinge-moment characteristics of an unshielded horn, of shielded horns of different chords, spans, and nose shapes, and of trimming tabs of two nose shapes indicated the following conclusions:

1. The addition of the shielded horns gave a change in hinge-moment variation with angle of attack about 60 percent as great as unshielded horns for the same balance coefficient. (The balance coefficient is the square root of the ratio of the product of the horn area and mean chord of the horn to the product of the rudder area and mean chord of the rudder.) For the shielded horns, the change in hinge-moment variation with rudder deflection was less than for the unshielded horn for horns of small balance coefficient and greater for horns of large balance coefficient. The ratio of the change in hinge-moment variation with angle of attack to change with rudder deflection was about 0.7 for the shielded horns.

2. For the XF6F vertical tail surface the rate of change of hinge-moment coefficient with rudder deflection could be reduced with shielded horns to about 50 percent of the unbalanced value without obtaining a positive value of the rate of change with angle of attack large enough to give steady oscillations of the airplane with free rudder.

3. For most tail surfaces it will be impossible to obtain a closely balanced surface by means of shielded horns and keep the rate of change of hinge-moment coefficient with angle of attack near zero without the addition of some other balancing device of which the main function is to reduce the negative hinge moment due to deflection.

4. The pressure-distribution tests showed that, in general, the medium-nose horn gave lower peak pressures and consequently higher critical speeds than the blunt-nose horn.

5. The two tabs tested gave approximately the same results.

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TABLE I.- ORDINATES FOR MEDIUM NOSE SHAPES

[Spanwise stations in in. from root section.
Chordwise stations and ordinates in in.]

Horns 1 and 4		
Chordwise station	Ordinates	
	Spanwise station 41.01	Spanwise station 54.62
0	0	0
.03	.152	.071
.08	.247	.115
.13	.314	.146
.23	.414	.193
.43	.556	.259
.93	.778	.363
1.43	.916	.427
2.43	1.050	.489
2.93	1.066	.496
3.43	1.050	.489
3.76	1.020	.475

Horns 2 and 5		
Chordwise station	Ordinates	
	Spanwise station 41.01	Spanwise station 54.62
0	0	0
.02	.100	.047
.05	.186	.086
.12	.242	.113
.22	.326	.152
.72	.576	.268
1.22	.732	.341
1.72	.845	.393
2.29	.942	.439
2.72	.999	.465
3.72	1.090	.507
4.72	1.133	.528
5.22	1.138	.530
5.72	1.133	.528
6.72	1.090	.507
7.52	1.020	.475

Horns 3 and 6		
Chordwise station	Ordinates	
	Spanwise station 41.01	Spanwise station 54.62
0	0	0
.05	.142	.066
.20	.284	.132
.30	.345	.161
.80	.554	.258
1.30	.694	.323
1.80	.800	.373
2.30	.887	.413
3.30	1.019	.474
4.30	1.111	.517
5.30	1.172	.546
6.30	1.206	.562
6.80	1.216	.566
7.30	1.218	.567
8.30	1.206	.562
9.30	1.172	.546
10.30	1.111	.517
10.80	1.069	.498
11.28	1.020	.475

Horns 7 and 8		
Chordwise station	Ordinates	
	Spanwise station 41.01	Spanwise station 54.62
0	0	0
.04	.142	.066
.17	.284	.132
.25	.345	.162
.68	.554	.258
1.10	.694	.323
1.53	.800	.373
1.95	.887	.413
2.80	1.019	.474
3.65	1.111	.517
4.50	1.172	.546
5.35	1.206	.562
5.77	1.216	.566
6.20	1.218	.567
7.05	1.206	.562
7.90	1.172	.546
8.74	1.111	.517
9.17	1.069	.498
9.58	1.020	.475

TABLE II.- SUMMARY OF CHARACTERISTICS
OF SHIELDED HORNS ON 0.7-SCALE MODEL
OF XF6F VERTICAL TAIL SURFACE

Horn	B	S_H/S_r	$C_{L\alpha}$	$C_{L\delta}$	$C_{h\alpha}$	$C_{h\delta}$
None	0	0	0.053	0.034	-0.0020	-0.0077
1-a	.106	.038	.052	.034	-.0014	-.0074
1-b	.106	.038	.052	.035	-.0016	-.0075
2-a	.210	.075	.052	.034	-.0007	-.0062
2-c	.210	.075	.050	.036	-.0010	-.0065
2-d	.210	.075	.052	.036	-.0006	-.0070
3-a	.310	.111	.053	.035	.0010	-.0037
3-b	.310	.111	.053	.034	.0008	-.0045
4-a	.151	.076	.054	.036	-.0013	-.0072
4-b	.151	.076	.053	.036	-.0017	-.0075
5-a	.303	.151	.054	.036	.0001	-.0037
5-b	.303	.151	.055	.036	.0005	-.0045
6-a	.453	.226	.054	.036	.0034	.0019
6-b	.453	.226	.053	.037	.0040	0
7-a	.268	.094	.054	.037	-.0002	-.0058
7-b	.268	.094	.054	.036	-.0003	-.0060
8-a	.386	.187	.053	.036	.0018	-.0013
8-b	.386	.187	.053	.036	.0017	-.0026

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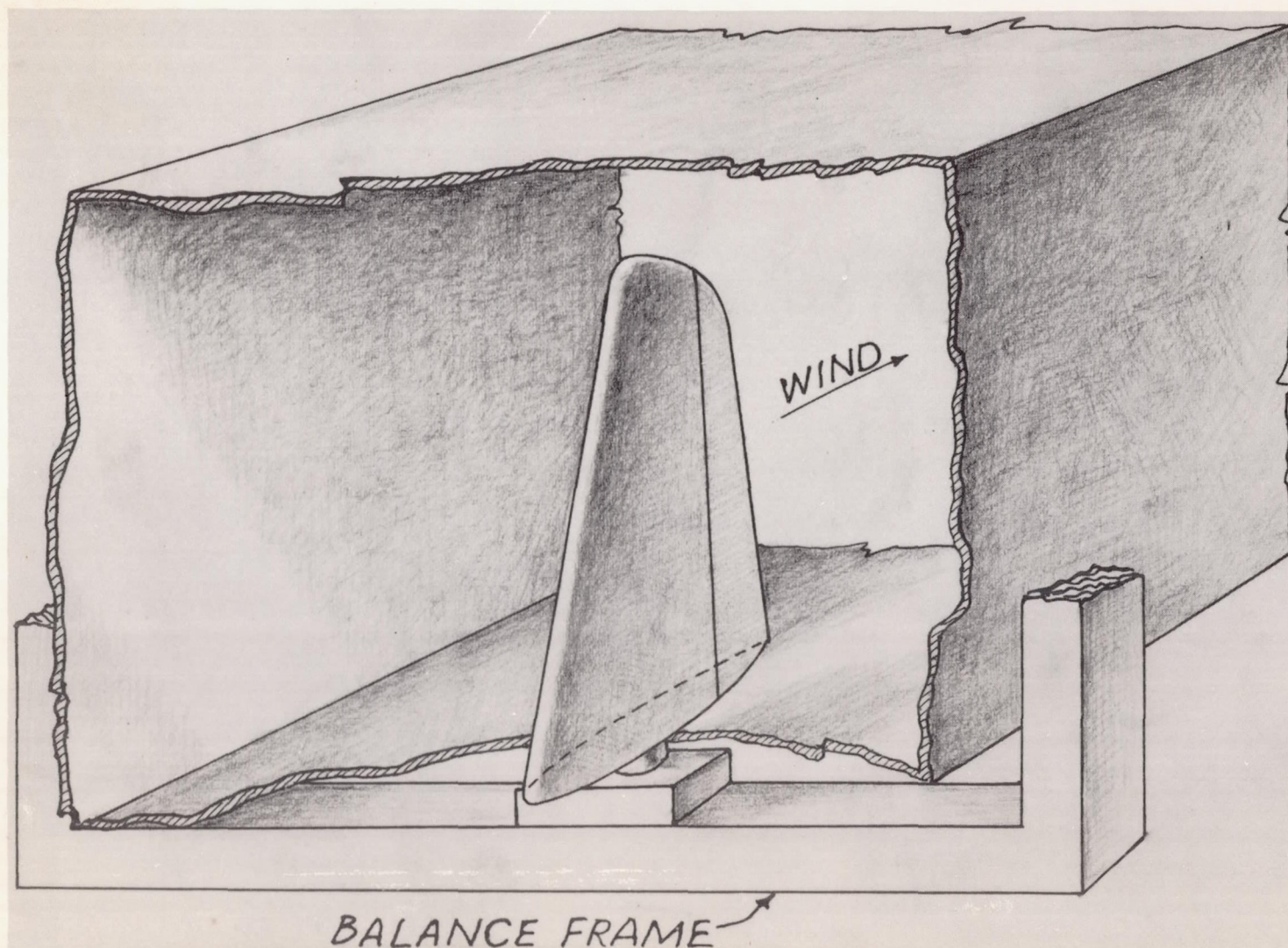


Figure 1.- Vertical-tail-surface setup in LMAL 7- by 10-foot tunnel

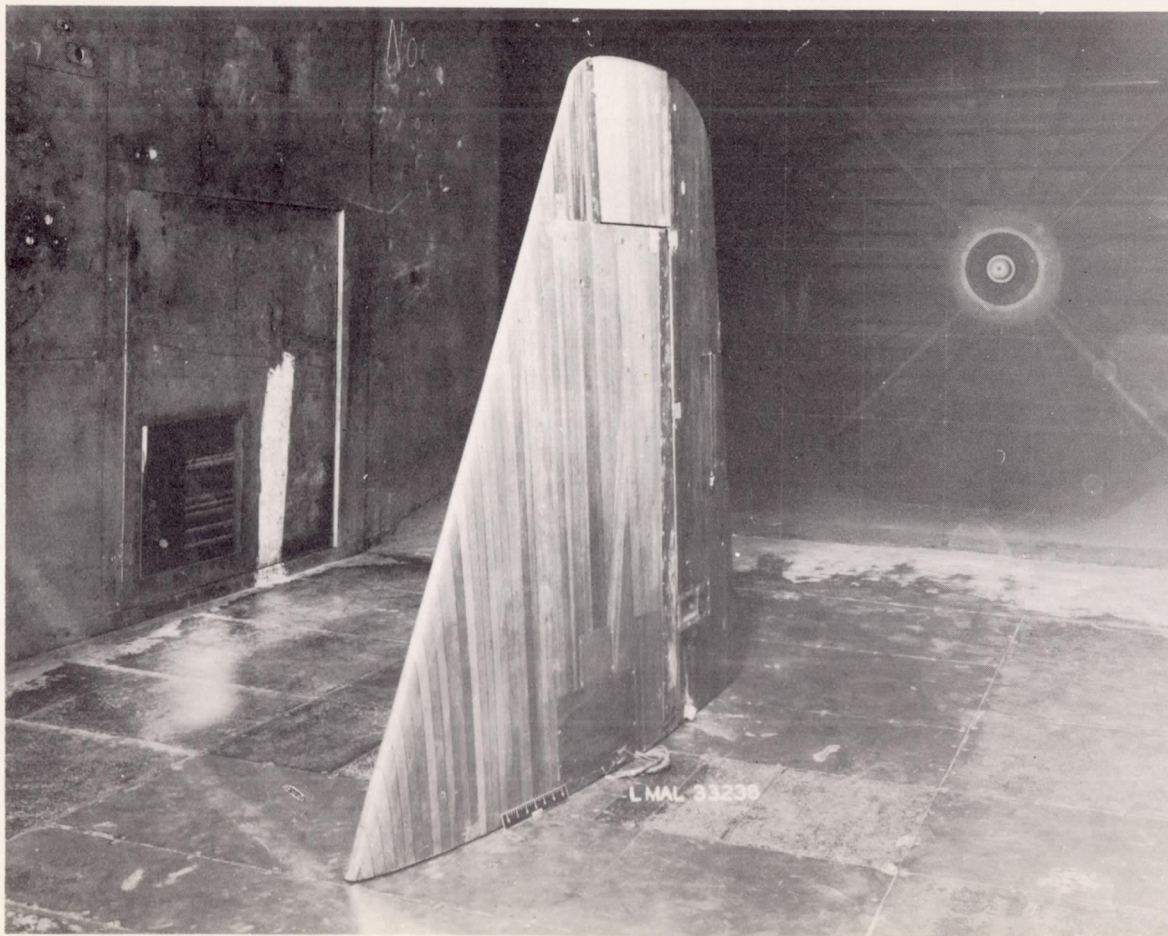


Figure 2.- Three-quarter front view of installation of 0.7-scale model of XF6F vertical tail surface in LMAL 7- by 10-foot tunnel.

Geometric characteristics of model	
Tail area	14.37 ft ²
Tail span	4.55 ft
Tail aspect ratio	1.43
Rudder area	4.68 ft ²
\bar{c}_r	1.03 ft
Tab area	0.31 ft ²
\bar{c}_t	0.32 ft

Airfoil section			
Station 0		Station 54.62	
Station	Ordinate	Station	Ordinate
0	0	0	0
.688	.770	.270	.116
1.376	1.076	.540	.161
2.752	1.496	1.080	.224
4.128	1.807	1.620	.271
5.504	2.061	2.160	.309
6.885	2.265	2.700	.370
8.267	2.420	3.240	.417
9.650	2.536	3.780	.484
11.033	2.612	4.320	.523
12.416	2.648	4.860	.536
13.799	2.644	5.400	.481
15.182	2.599	5.940	.433
16.565	2.524	6.480	.373
17.948	2.419	7.020	.303
19.331	2.284	7.560	.224
20.714	2.129	8.100	.136
22.097	1.954	8.640	.048
23.480	1.759	9.180	0
24.863	1.544	9.720	
26.246	1.309	10.260	
27.629	1.054	10.800	
29.012	.779	11.340	
30.395	.484	11.880	
31.778	.169	12.420	
33.161	0	12.960	
34.544		13.500	
35.927		14.040	
37.310		14.580	
38.693		15.120	
40.076		15.660	
41.459		16.200	
42.842		16.740	
44.225		17.280	
45.608		17.820	
46.991		18.360	
48.374		18.900	
49.757		19.440	
51.140		19.980	
52.523		20.520	
53.906		21.060	
55.289		21.600	
56.672		22.140	
58.055		22.680	
59.438		23.220	
60.821		23.760	
62.204		24.300	
63.587		24.840	
64.970		25.380	
66.353		25.920	
67.736		26.460	
69.119		27.000	
70.502		27.540	
71.885		28.080	
73.268		28.620	
74.651		29.160	
76.034		29.700	
77.417		30.240	
78.800		30.780	
80.183		31.320	
81.566		31.860	
82.949		32.400	
84.332		32.940	
85.715		33.480	
87.098		34.020	
88.481		34.560	
89.864		35.100	
91.247		35.640	
92.630		36.180	
94.013		36.720	
95.396		37.260	
96.779		37.800	
98.162		38.340	
99.545		38.880	
100.928		39.420	
102.311		39.960	
103.694		40.500	
105.077		41.040	
106.460		41.580	
107.843		42.120	
109.226		42.660	
110.609		43.200	
111.992		43.740	
113.375		44.280	
114.758		44.820	
116.141		45.360	
117.524		45.900	
118.907		46.440	
120.290		46.980	
121.673		47.520	
123.056		48.060	
124.439		48.600	
125.822		49.140	
127.205		49.680	
128.588		50.220	
129.971		50.760	
131.354		51.300	
132.737		51.840	
134.120		52.380	
135.503		52.920	
136.886		53.460	
138.269		54.000	
139.652		54.540	
141.035		55.080	
142.418		55.620	
143.801		56.160	
145.184		56.700	
146.567		57.240	
147.950		57.780	
149.333		58.320	
150.716		58.860	
152.099		59.400	
153.482		59.940	
154.865		60.480	
156.248		61.020	
157.631		61.560	
159.014		62.100	
160.397		62.640	
161.780		63.180	
163.163		63.720	
164.546		64.260	
165.929		64.800	
167.312		65.340	
168.695		65.880	
170.078		66.420	
171.461		66.960	
172.844		67.500	
174.227		68.040	
175.610		68.580	
176.993		69.120	
178.376		69.660	
179.759		70.200	
181.142		70.740	
182.525		71.280	
183.908		71.820	
185.291		72.360	
186.674		72.900	
188.057		73.440	
189.440		73.980	
190.823		74.520	
192.206		75.060	
193.589		75.600	
194.972		76.140	
196.355		76.680	
197.738		77.220	
199.121		77.760	
200.504		78.300	
201.887		78.840	
203.270		79.380	
204.653		79.920	
206.036		80.460	
207.419		81.000	
208.802		81.540	
210.185		82.080	
211.568		82.620	
212.951		83.160	
214.334		83.700	
215.717		84.240	
217.100		84.780	
218.483		85.320	
219.866		85.860	
221.249		86.400	
222.632		86.940	
224.015		87.480	
225.398		88.020	
226.781		88.560	
228.164		89.100	
229.547		89.640	
230.930		90.180	
232.313		90.720	
233.696		91.260	
235.079		91.800	
236.462		92.340	
237.845		92.880	
239.228		93.420	
240.611		93.960	
241.994		94.500	
243.377		95.040	
244.760		95.580	
246.143		96.120	
247.526		96.660	
248.909		97.200	
250.292		97.740	
251.675		98.280	
253.058		98.820	
254.441		99.360	
255.824		99.900	
257.207		100.440	
258.590		100.980	
260.073		101.520	
261.456		102.060	
262.839		102.600	
264.222		103.140	
265.605		103.680	
266.988		104.220	
268.371		104.760	
269.754		105.300	
271.137		105.840	
272.520		106.380	
273.903		106.920	
275.286		107.460	
276.669		108.000	
278.052		108.540	
279.435		109.080	
280.818		109.620	
282.201		110.160	
283.584		110.700	
284.967		111.240	
286.350		111.780	
287.733		112.320	
289.116		112.860	
290.499		113.400	
291.882		113.940	
293.265		114.480	
294.648		115.020	
296.031		115.560	
297.414		116.100	
298.797		116.640	
300.180		117.180	
301.563		117.720	
302.946		118.260	
304.329		118.800	
305.712		119.340	
307.095		119.880	
308.478		120.420	
309.861		120.960	
311.244		121.500	
312.627		122.040	
314.010		122.580	
315.393		123.120	
316.776		123.660	
318.159		124.200	
319.542		124.740	
320.925		125.280	
322.308		125.820	
323.691		126.360	
325.074		126.900	
326.457		127.440	
327.840		127.980	
329.223		128.520	
330.606		129.060	
331.989		129.600	
333.372		130.140	
334.755		130.680	
336.138		131.220	
337.521		131.760	
338.904		132.300	
340.287		132.840	
341.670		133.380	
343.053		133.920	
344.436		134.460	
345.819		135.000	
347.202		135.540	
348.585		136.080	
349.968		136.620	
351.351		137.160	
352.734		137.700	
354.117		138.240	
355.500		138.780	
356.883		139.320	
358.266		139.860	
359.649		140.400	
361.032		140.940	
362.415		141.480	
363.798		142.020	
365.181		142.560	
366.564		143.100	
367.947		143.640	
369.330		144.180	
370.713		144.720	
372.096		145.260	
373.479		145.800	
374.862		146.340	
376.245		146.880	
377.628		147.420	
379.011		147.960	
380.394		148.500	
381.777		149.040	
383.160		149.580	
384.543		150.120	
385.926		150.660	
387.309		151.200	
388.692		151.740	
390.075		152.280	
391.458		152.820	
392.841		153.360	
394.224		153.900	
395.607		154.440	
396.990		154.980	
398.373		155.520	
399.756		156.060	
401.139		156.600	
402.522		157.140	
403.905		157.680	
405.288		158.220	
406.671		158.760	
408.054		159.300	
409.437		159.840	
410.820		160.380	
412.203		160.920	
413.586		161.460	
414.969		162.000	
416.352		162.540	
417.735		163.080	
419.118		163.620	
420.501		164.160	
421.884		164.700	
423.267		165.240	
424.650		165.780	
426.033		166.320	
427.416		166.860	
428.799		167.400	
430.182		167.940	
431.565		168.480	
432.948		169.020	
434.331		169.560	
435.714		170.100	
437.097		170.640	
438.480		171.180	
439.863		171.720	
441.246		172.260	
442.629		172.800	
444.012		173.340	
445.395		173.880	
446.778		174.420	
448.161		174.960	
449.544		175.500	
450.927		176.040	
452.310		176.580	
453.693		177.120	
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456.459		178.200	
457.842		178.740	
459.225		179.280	
460.608		179.820	
461.991		180.360	
463.374		180.900	
464.757		181.440	
466.140		181.980	
467.523		182.520	
468.906		183.060	
470.289		183.600	
471.672		184.140	
473.055		184.680	
474.438			

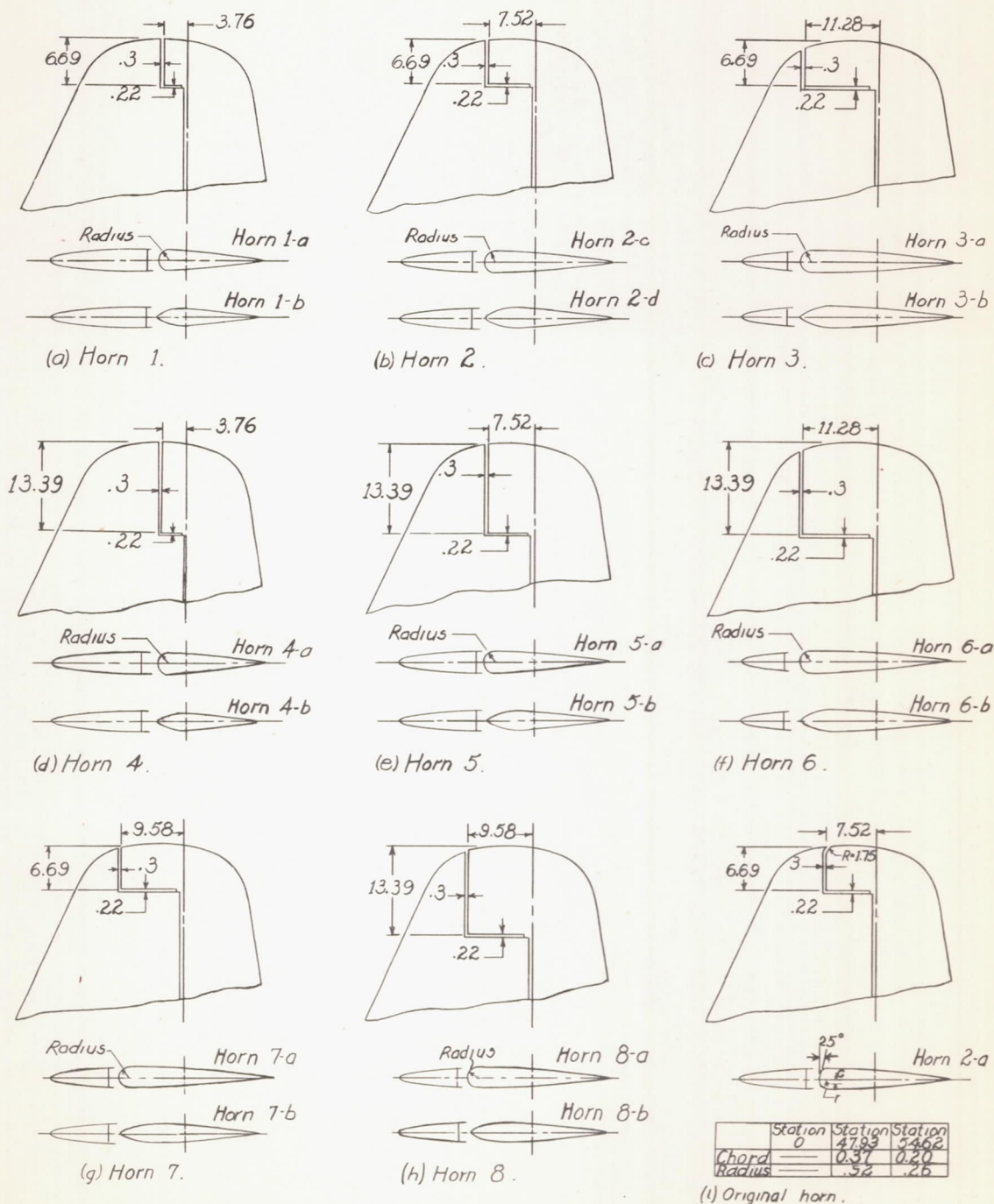
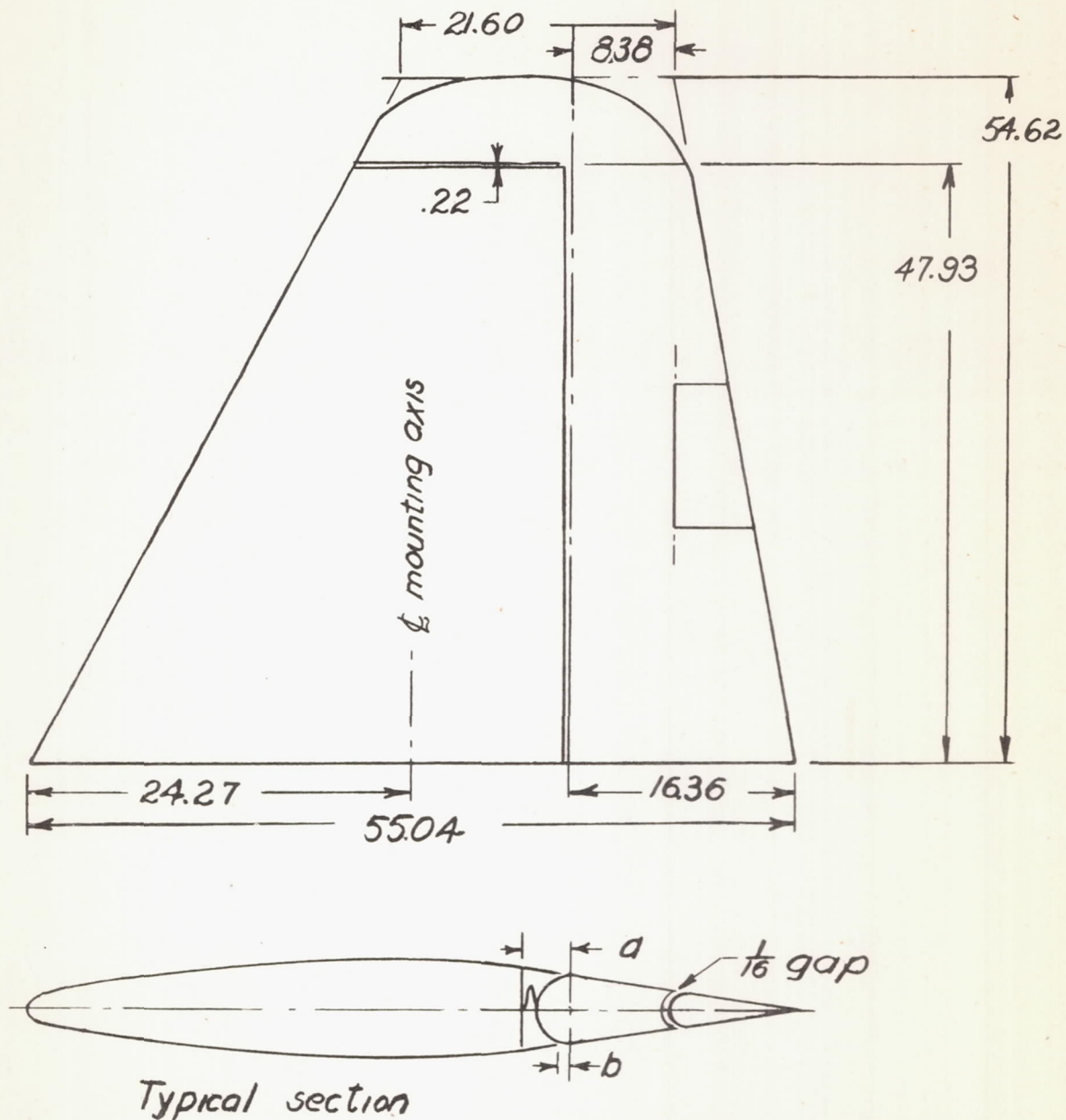


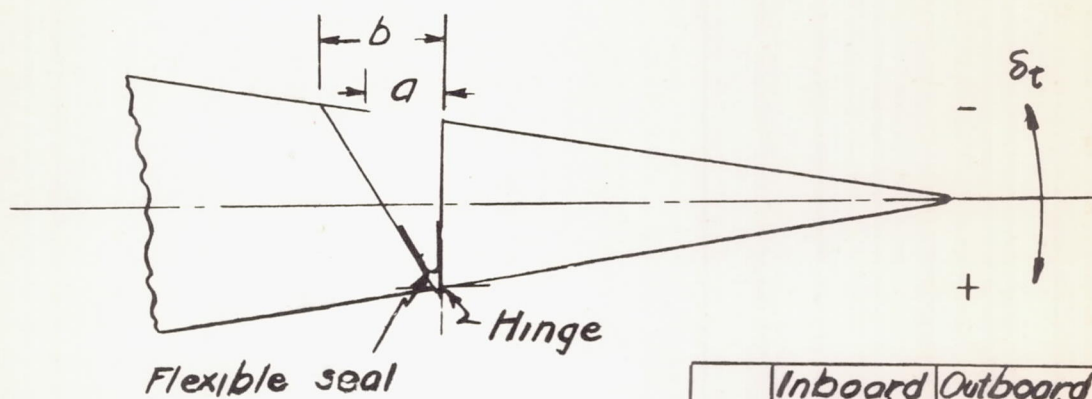
Figure 4.- Shielded horn balances tested on 0.7-scale model of XF6F vertical tail surface. (All dimensions are in in.)

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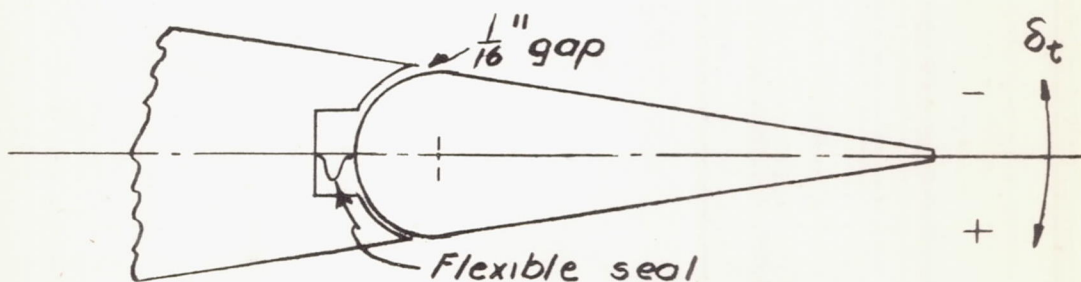
	Station 0	Station 47.93
<i>a</i>	3.03	1.33
<i>b</i>	.61	.61

Figure 5.- The 0.7-scale model of XF6F vertical tail surface with unshielded horn. (All dimensions are in in.)



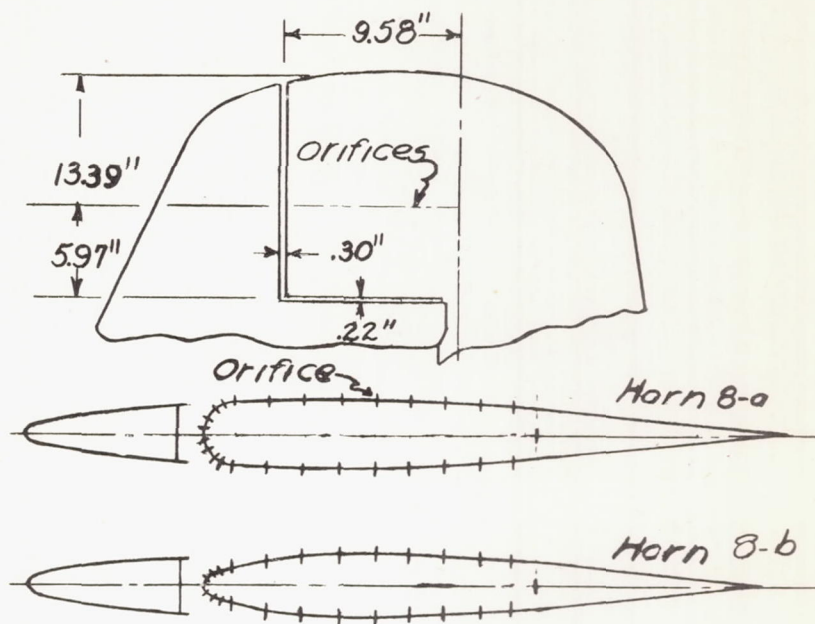
	Inboard end (in.)	Outboard end (in.)
a	0.65	0.37
b	.90	.53

(a) Original tab.



(b) Round-nose tab.

Figure 6.- Tabs tested on 0.7-scale model of XF6F vertical tail surface.



Horn 8-a	
Orifice location in in. from horn L.E.	
Orifice	Location
0	0
1	.03
2	.13
3	.25
4	.50
5	1.00
6	2.00
7	3.00
8	4.00
9	5.00
10	6.00
11	7.00
12	8.00
13	9.00

Horn 8-b	
Orifice location in in. from horn L.E.	
Orifice	Location
0	0
1	.13
2	.25
3	.50
4	1.00
5	2.00
6	3.00
7	4.00
8	5.00
9	6.00
10	7.00
11	8.00
12	9.00

Figure 7.- Location of pressure orifices on horns 8-a and 8-b on 0.7-scale model of XF6F vertical tail surface.

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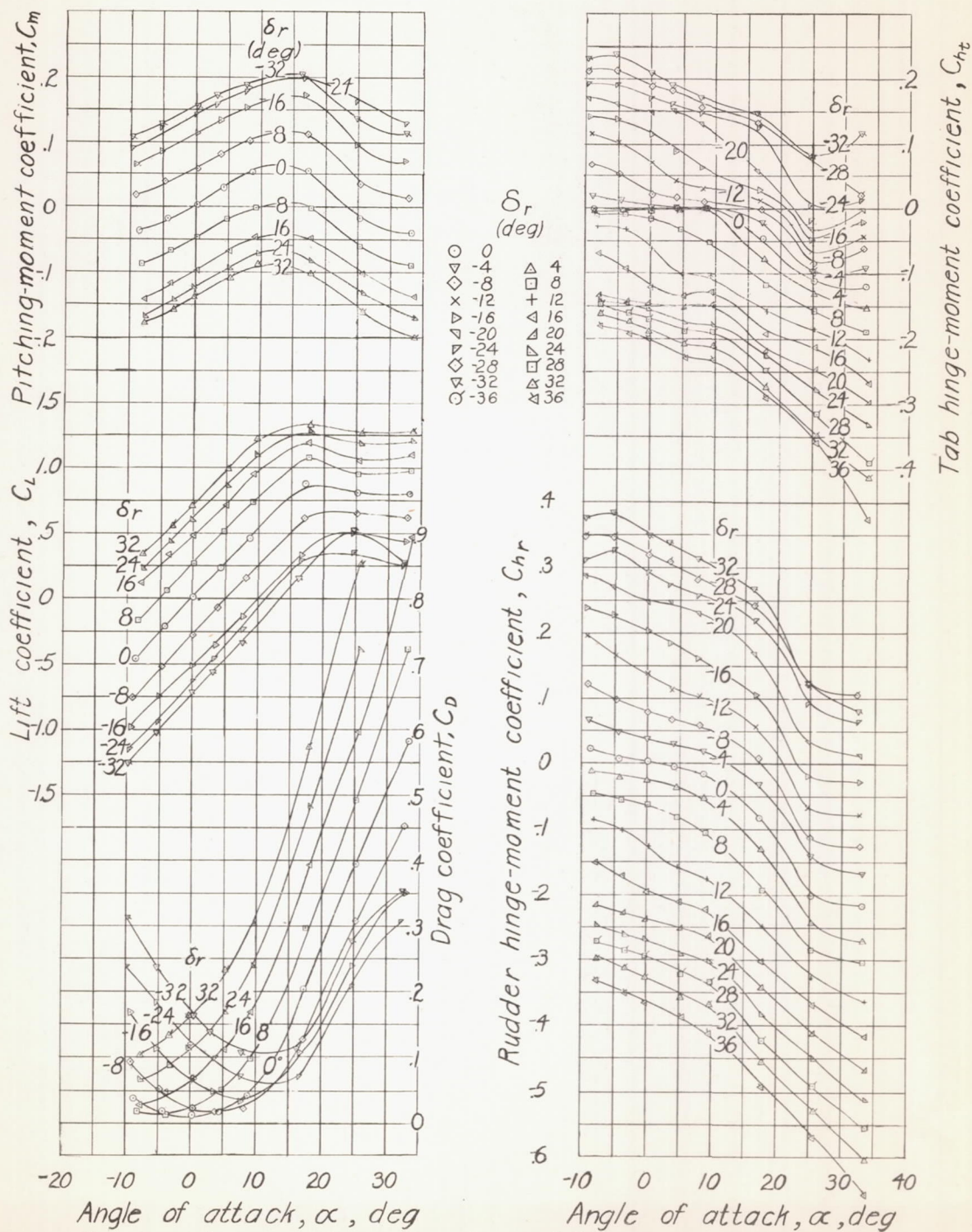


Figure 8.- Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface. Plain rudder. $\delta_t = 0^\circ$.

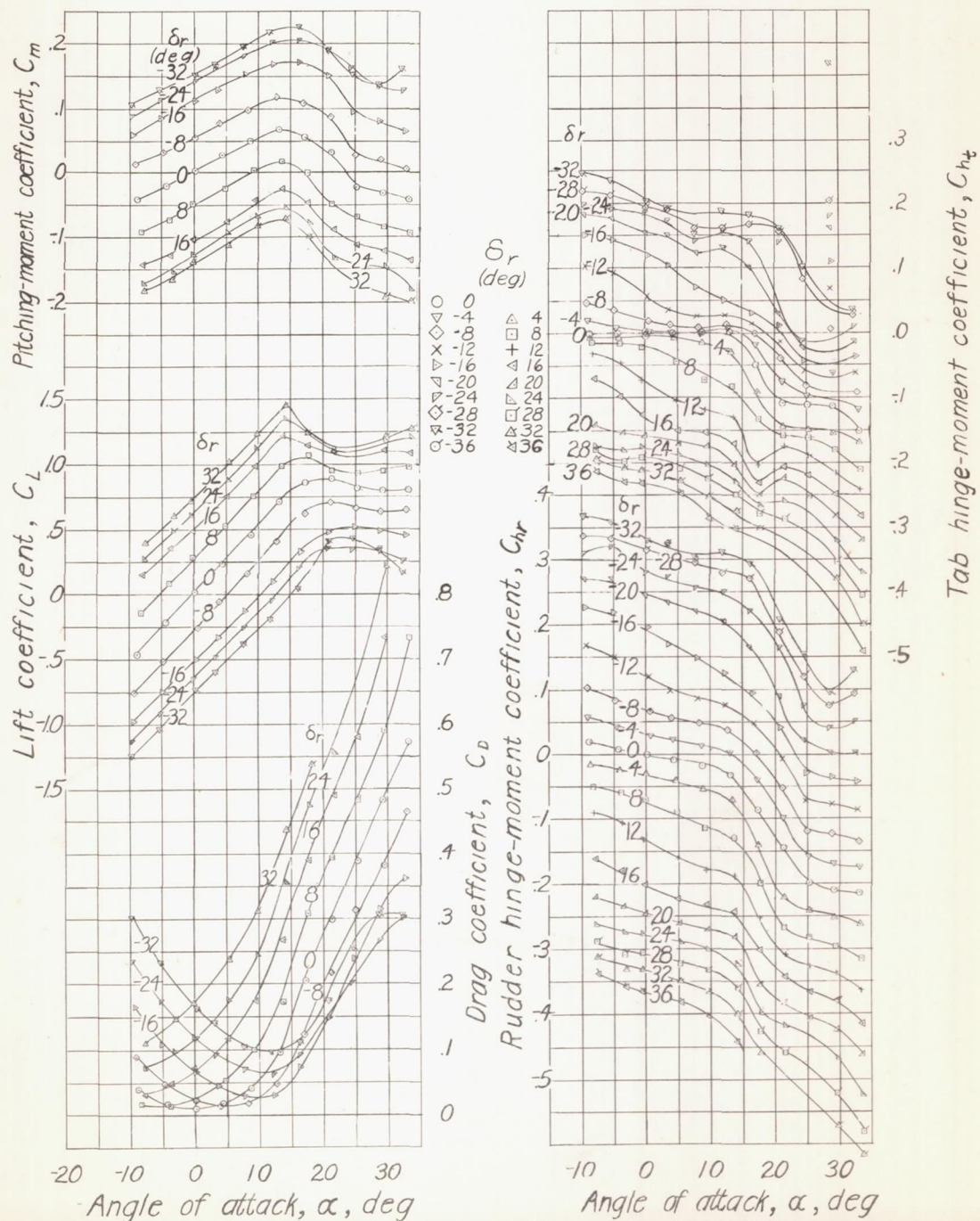


Figure 9.-Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface. Plain sealed rudder. Original tab; $\delta_t = 0^\circ$.

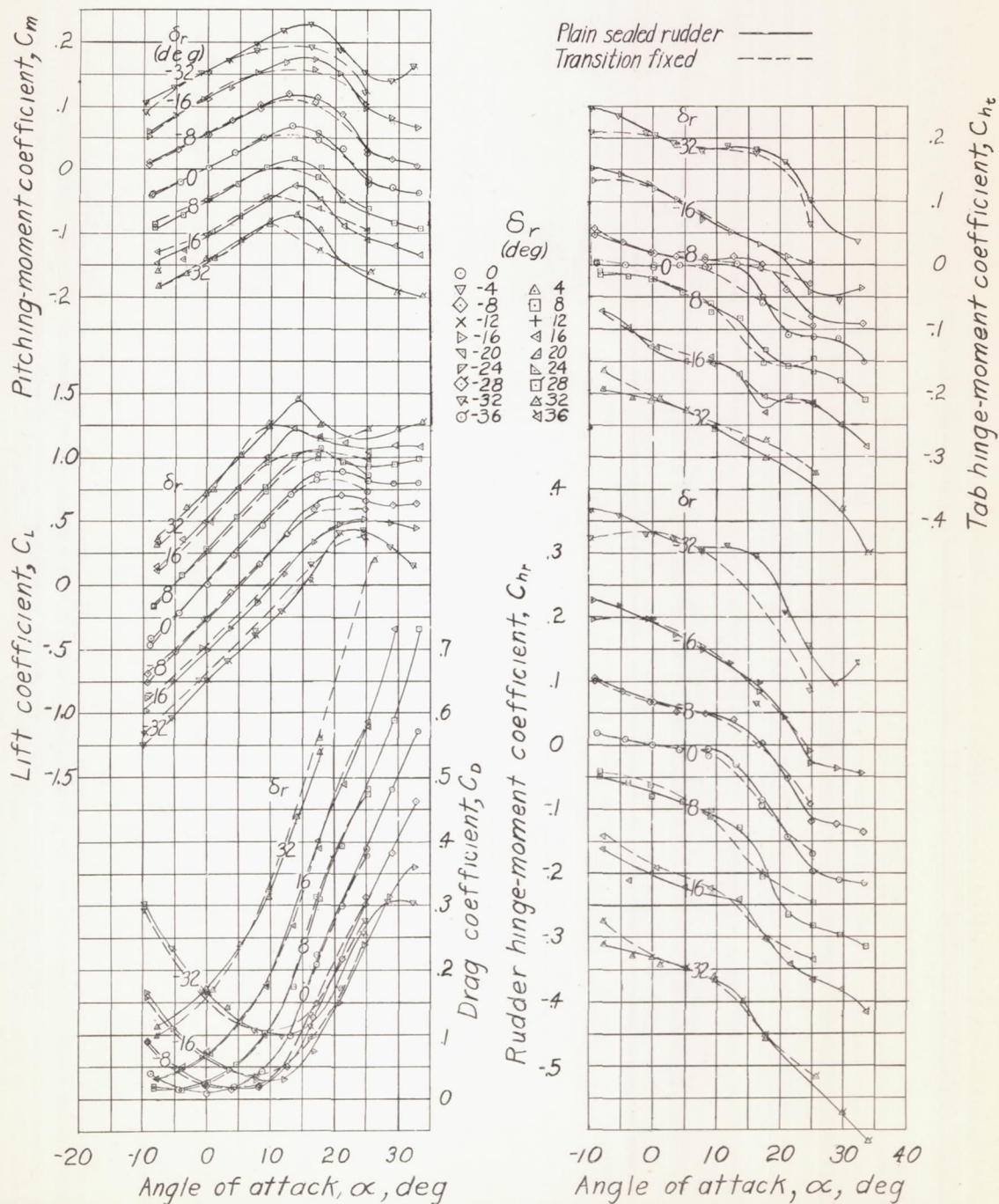


Figure 10.-Effect of fixing transition on the aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface. Plain sealed rudder. Original tab; $\delta_t = 0^\circ$.

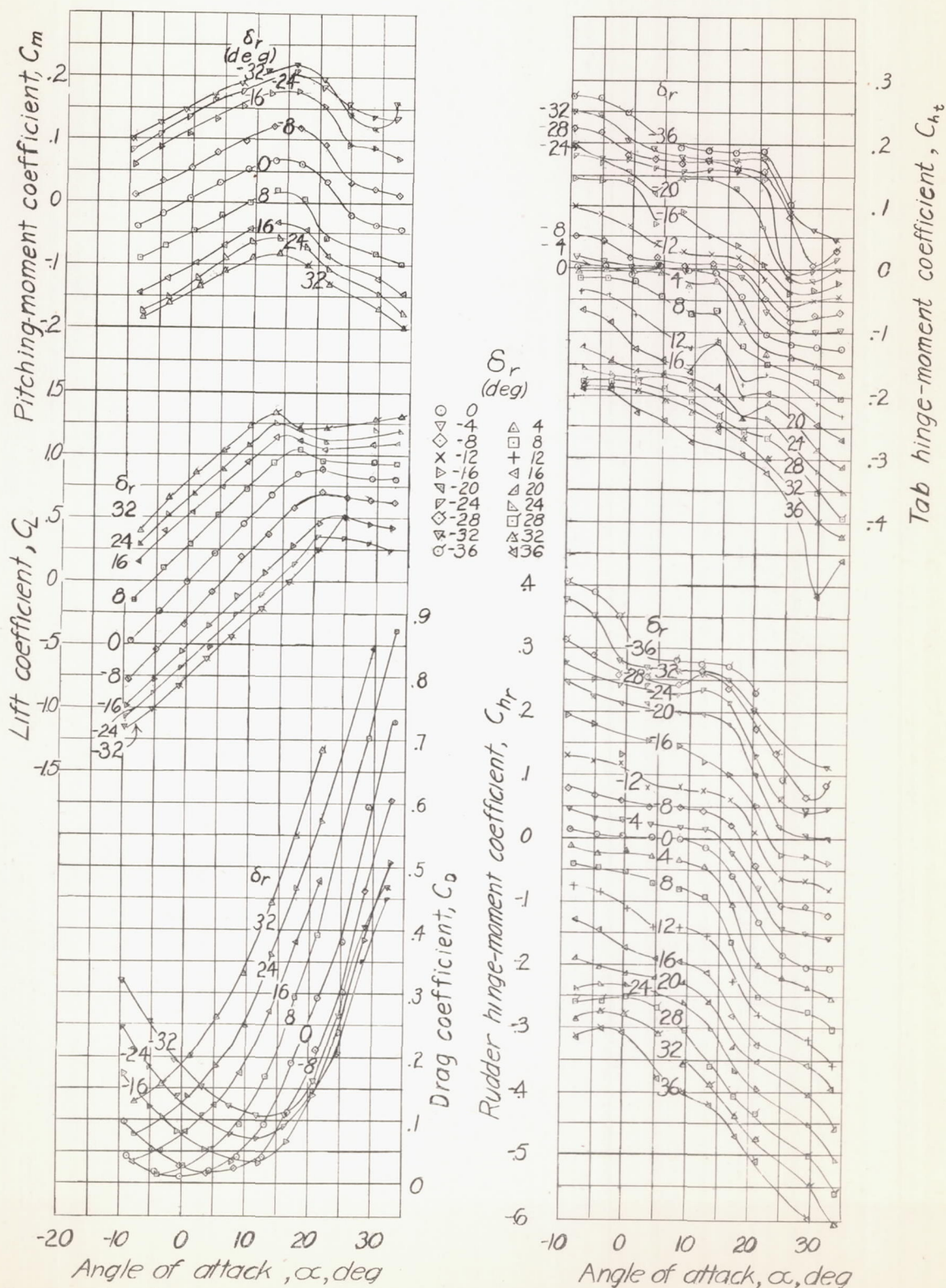


Figure 11.-Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface with shielded horn 2-a. Rudder gap sealed.

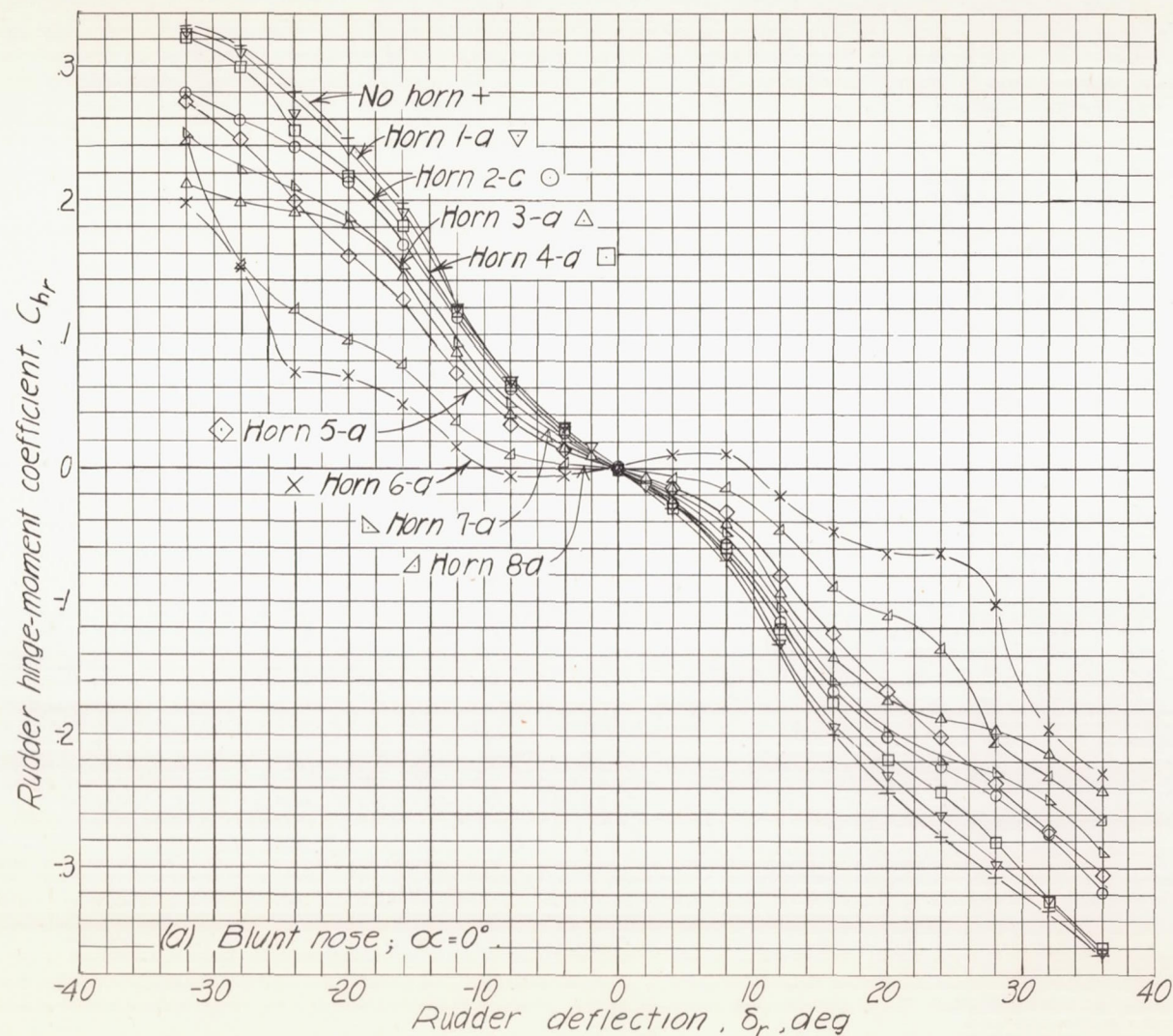


Figure 12. -Hinge-moment characteristics of the 0.7-scale model of XFGF vertical tail surface with several shielded-horn balances. Rudder gap sealed.

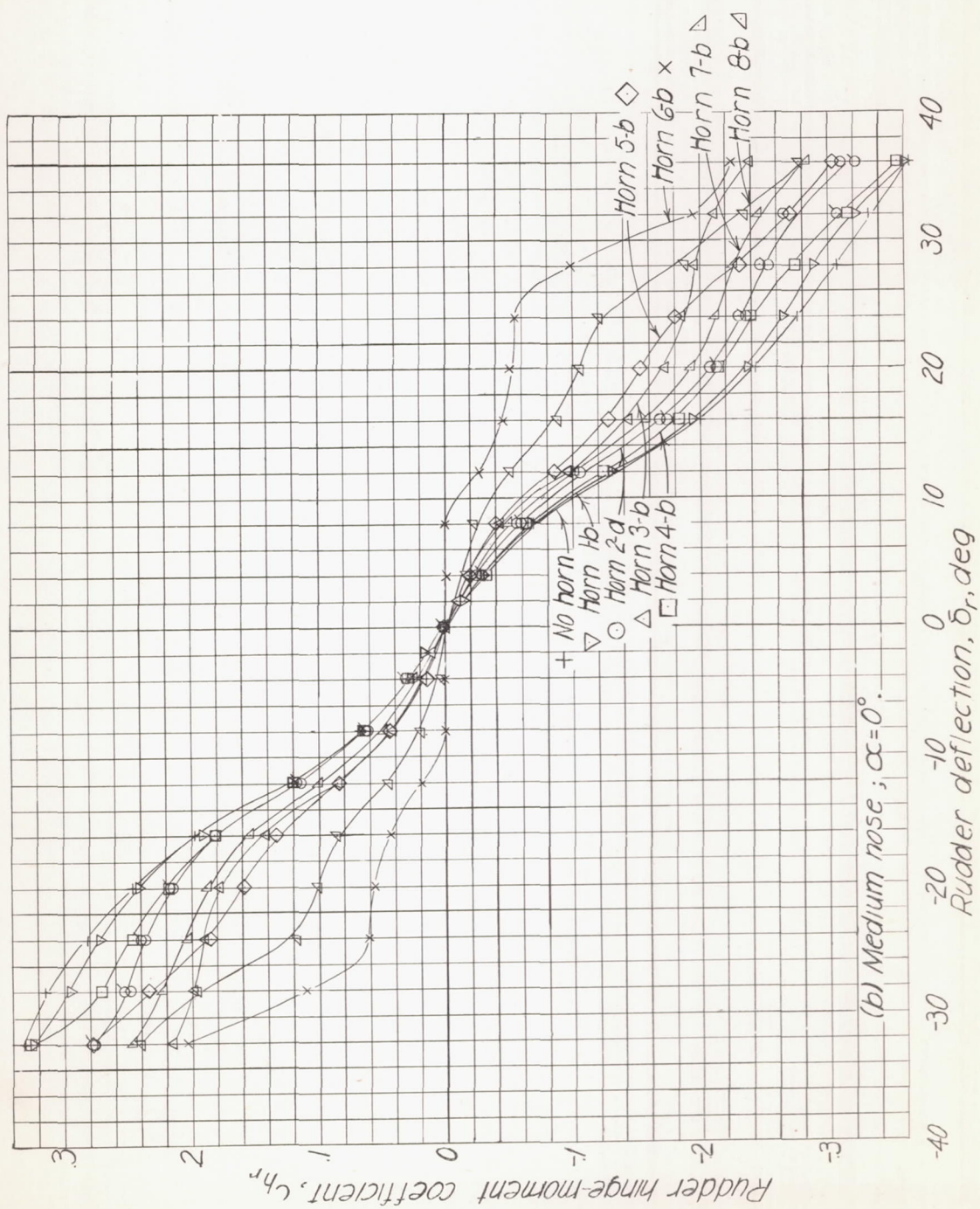


Figure 12.- Continued.

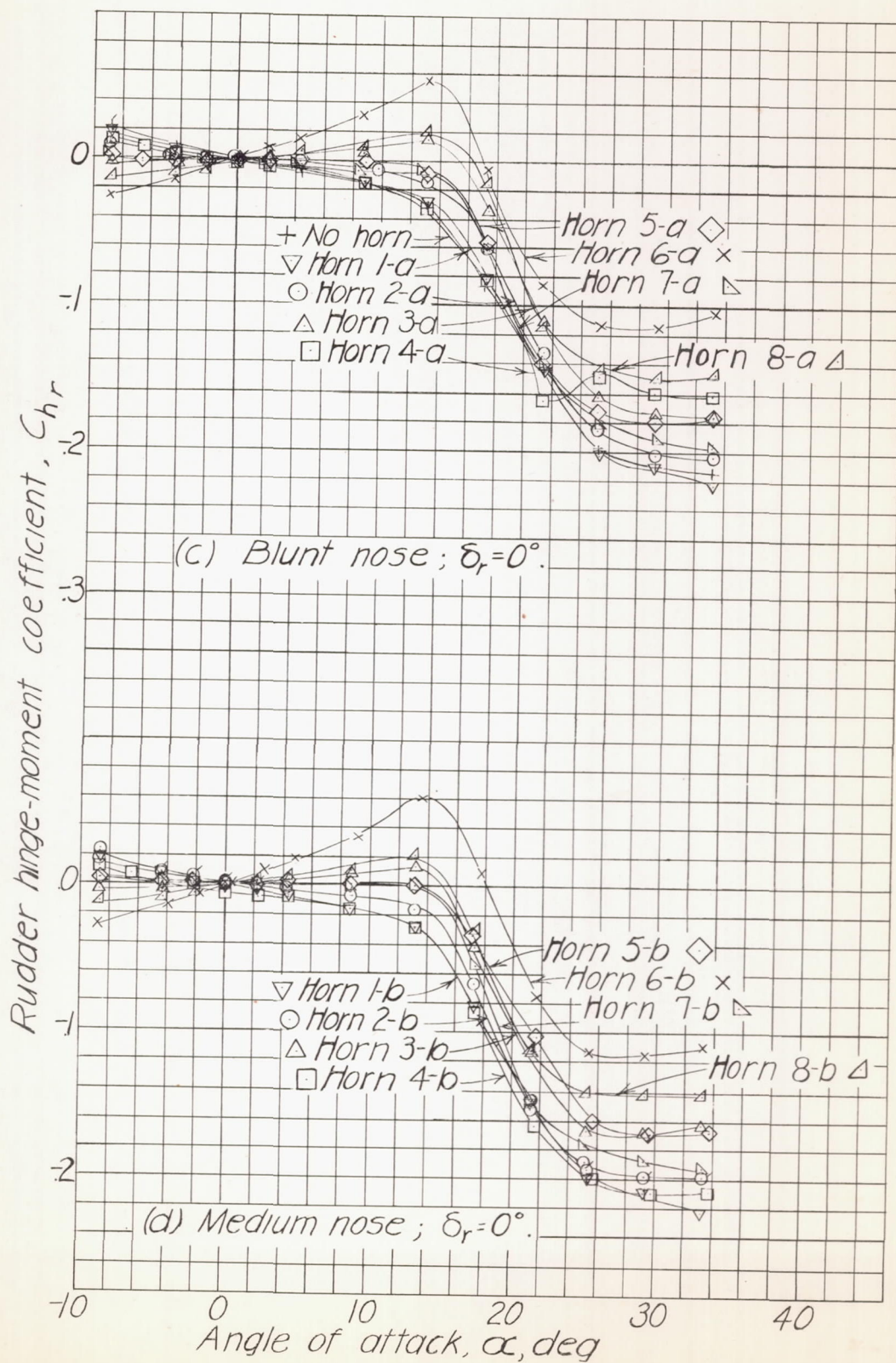


Figure 12.- Concluded.

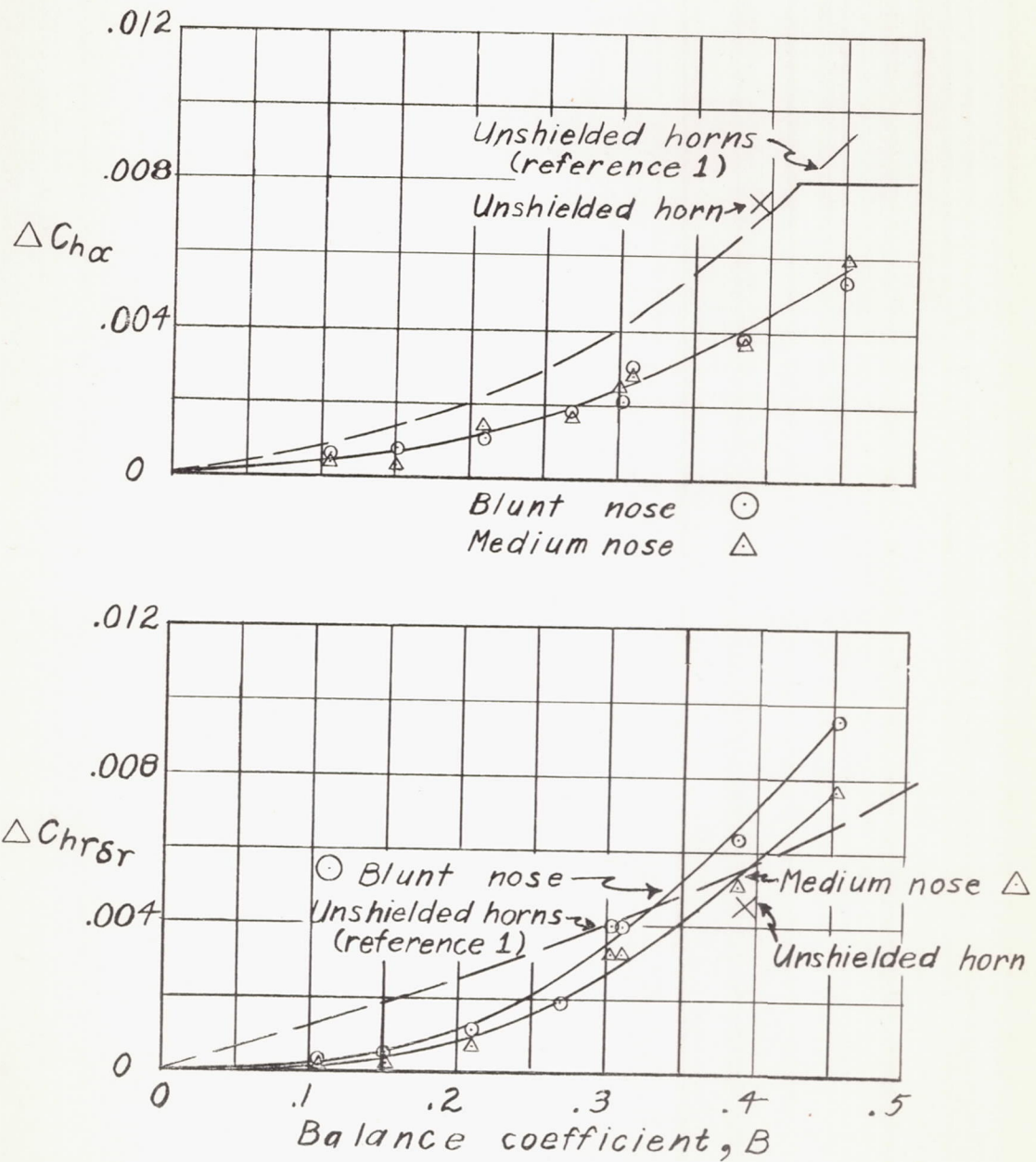


Figure 13.- Variation of $\Delta C_{h\alpha}$ and $\Delta C_{hr\delta r}$ with balance coefficient B . Shielded horns on 0.7-scale model of XF6F vertical tail.

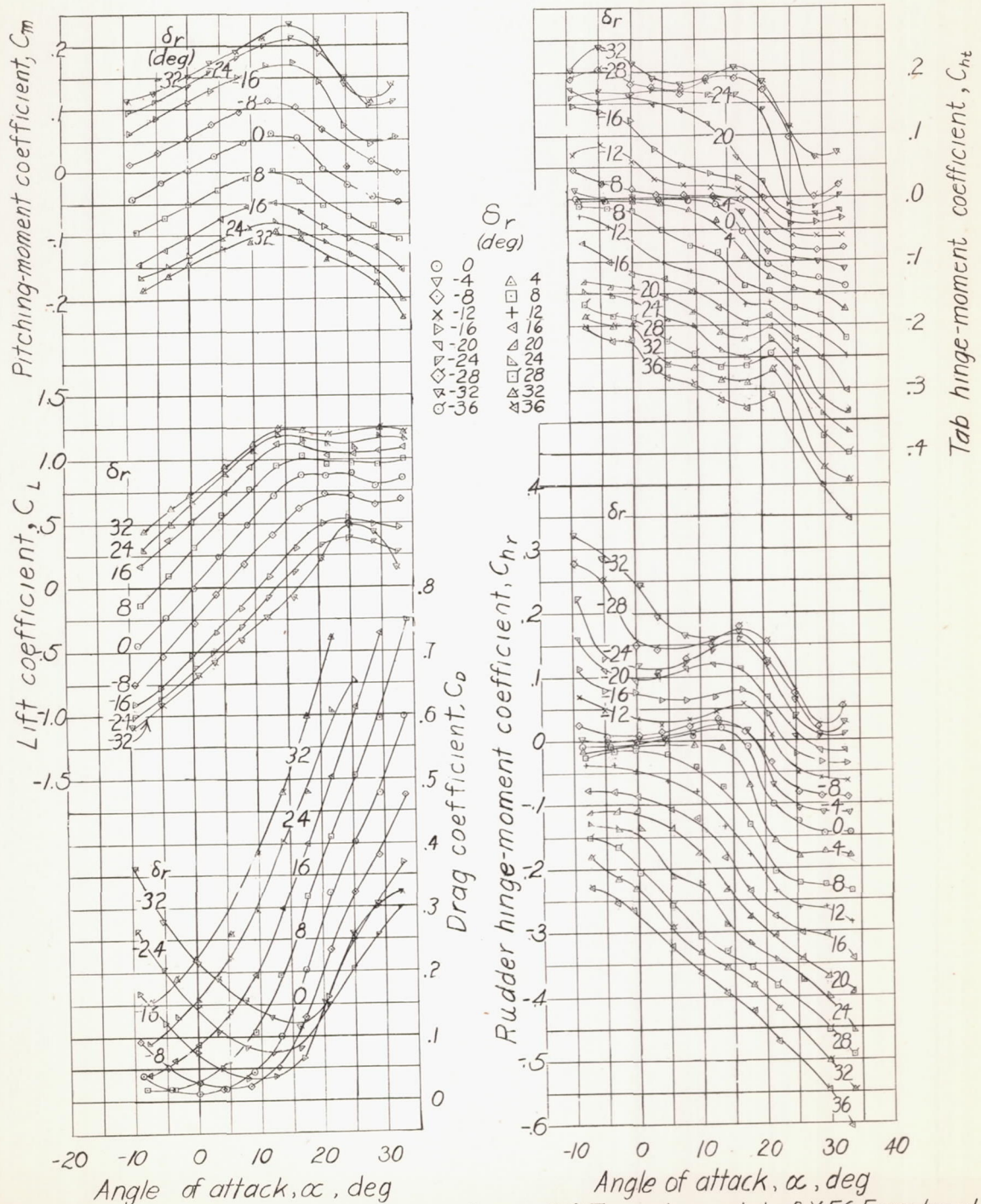


Figure 14. - Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface with shielded horn 8-a. Rudder gap sealed.

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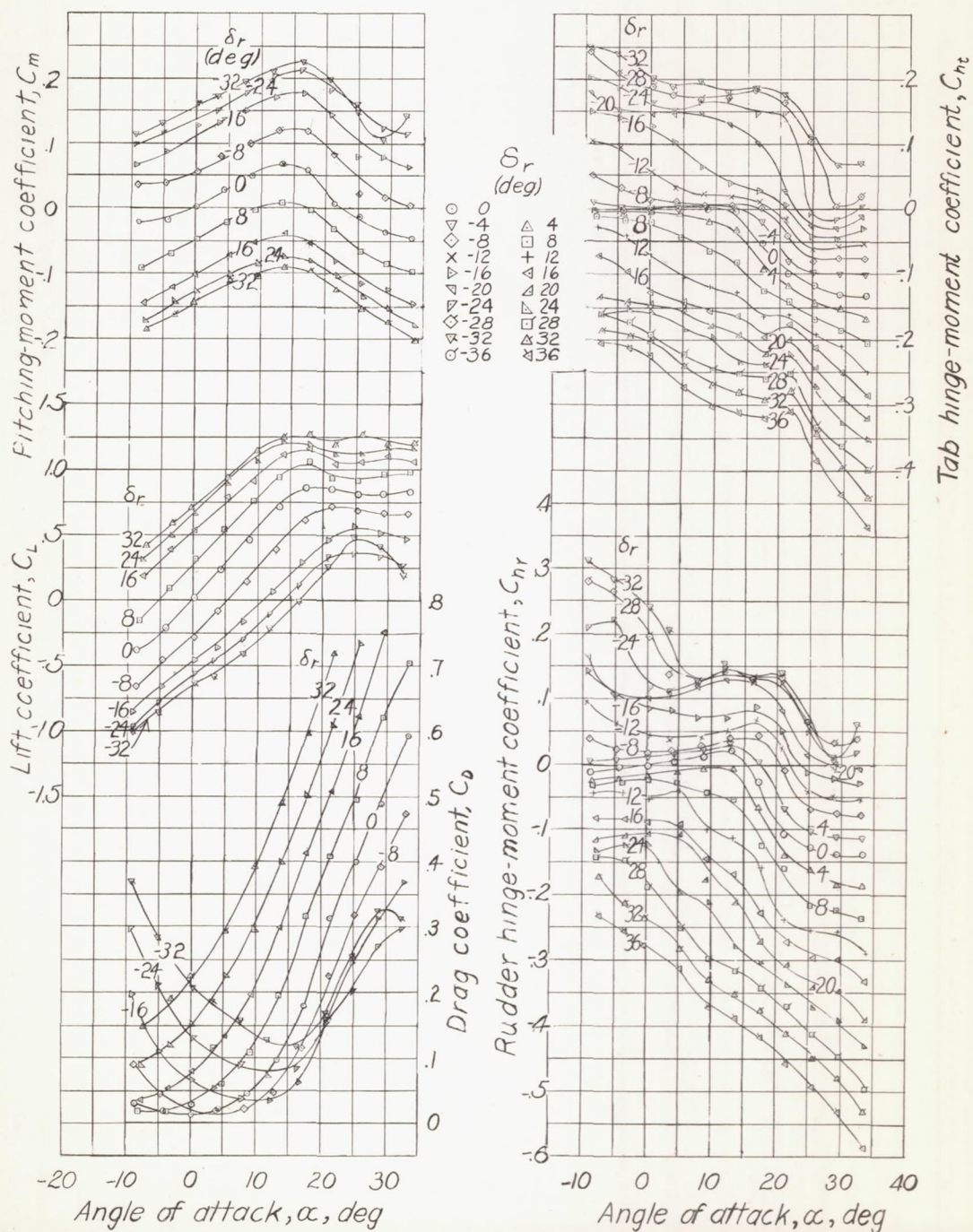


Figure 15. Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface with shielded horn 8-b. Rudder gap sealed.

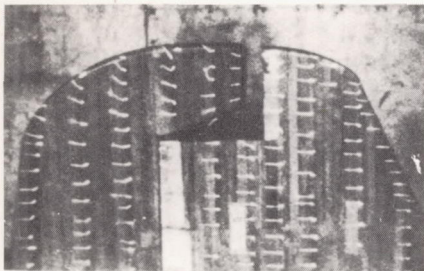
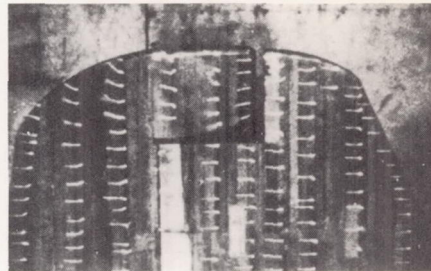
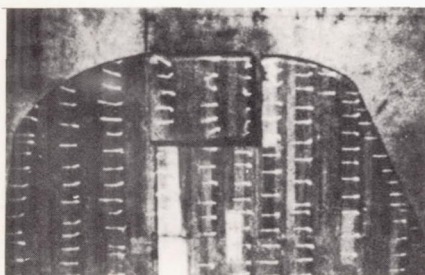
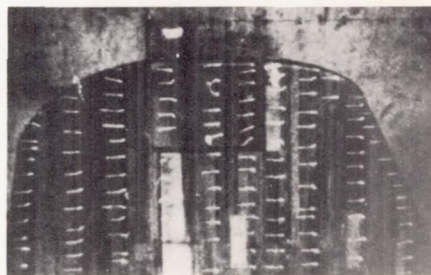
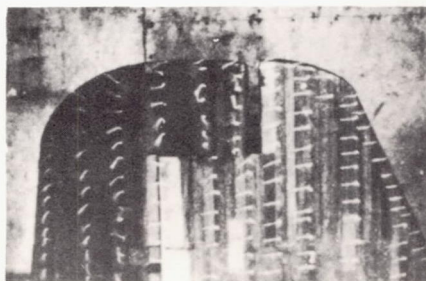
(a) $\alpha = 0^\circ; \delta_r = -24^\circ$.(b) $\alpha = 0^\circ; \delta_r = -12 \frac{1}{2}^\circ$.(c) $\alpha = 0^\circ; \delta_r = -6^\circ$.(d) $\alpha = 0^\circ; \delta_r = -3 \frac{1}{2}^\circ$.(e) $\alpha = 0^\circ; \delta_r = 24^\circ$.

Figure 16.- Tuft study over upper surface of 0.7-scale model of XF6F vertical tail with horn 2-c.

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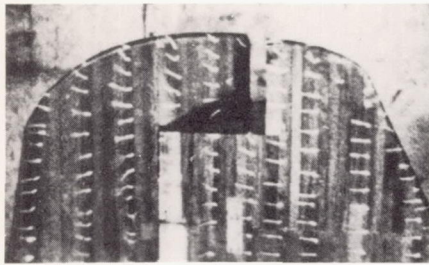
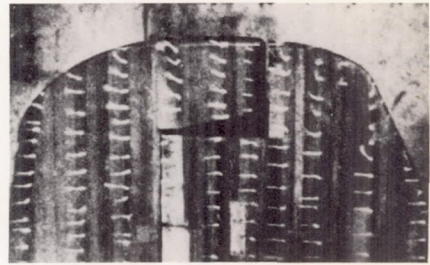
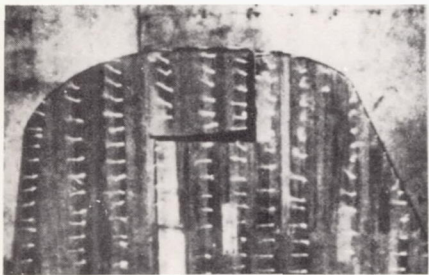
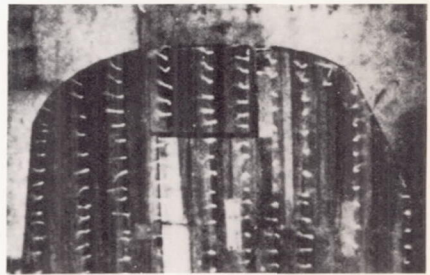
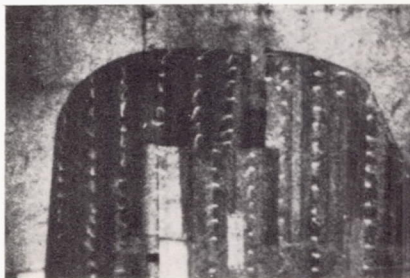
(f) $\alpha = 12^\circ$; $\delta_r = -36^\circ$.(g) $\alpha = 12^\circ$; $\delta_r = -16^\circ$.(h) $\alpha = 12^\circ$; $\delta_r = -8^\circ$.(i) $\alpha = 12^\circ$; $\delta_r = 0^\circ$.(j) $\alpha = 12^\circ$; $\delta_r = 24^\circ$.

Figure 16.- Concluded.

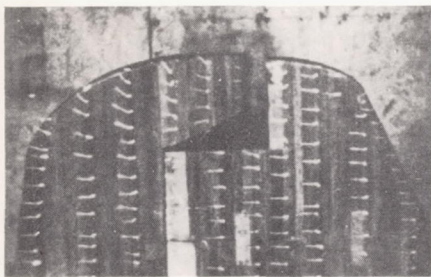
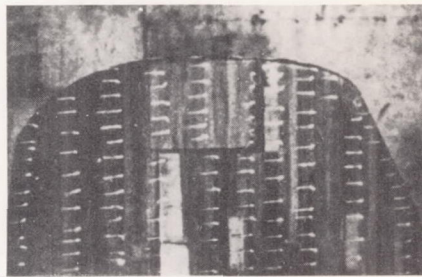
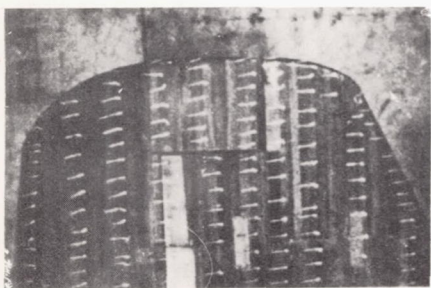
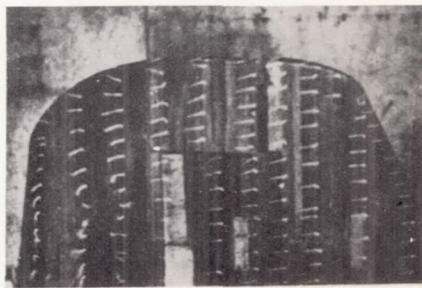
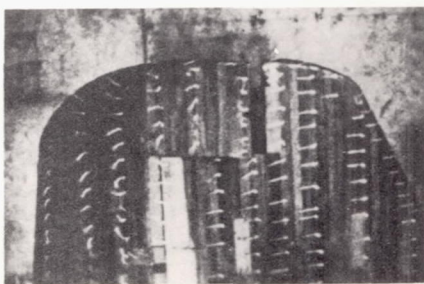
(a) $\alpha = 0^\circ; \delta_r = -24^\circ$.(b) $\alpha = 0^\circ; \delta_r = 0^\circ$.(c) $\alpha = 0^\circ; \delta_r = 8^\circ$.(d) $\alpha = 0^\circ; \delta_r = 16^\circ$.(e) $\alpha = 0^\circ; \delta_r = 24^\circ$.

Figure 17.- Tuft study over upper surface of 0.7-scale model of XF6F vertical tail with horn 2-d.

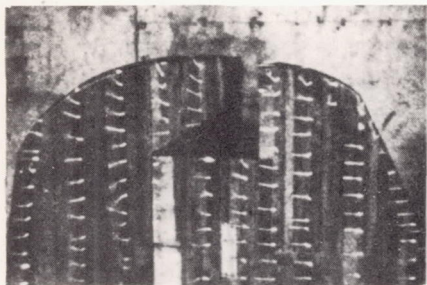
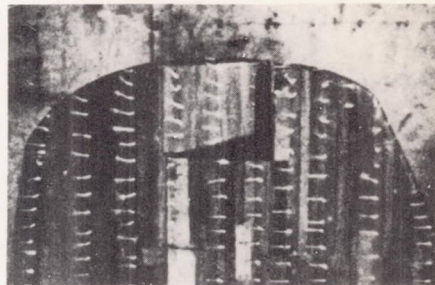
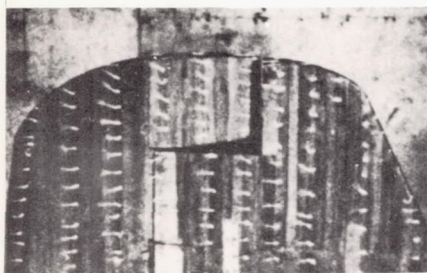
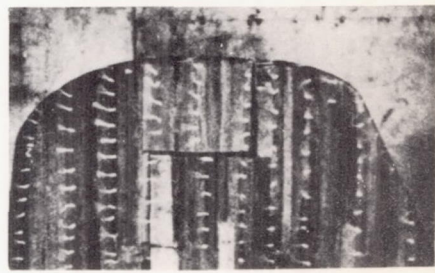
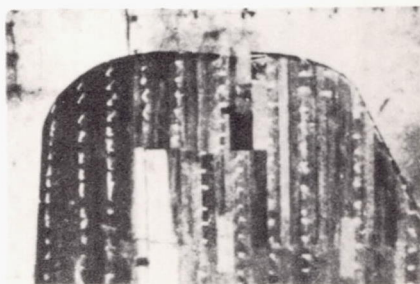
(f) $\alpha = 12^\circ; \delta_r = -32^\circ$.(g) $\alpha = 12^\circ; \delta_r = -16^\circ$.(h) $\alpha = 12^\circ; \delta_r = -8^\circ$.(i) $\alpha = 12^\circ; \delta_r = 0^\circ$.(j) $\alpha = 12^\circ; \delta_r = 24^\circ$.

Figure 17.- Concluded.

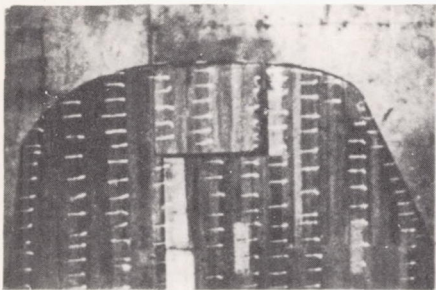
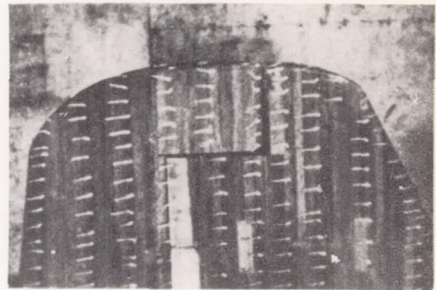
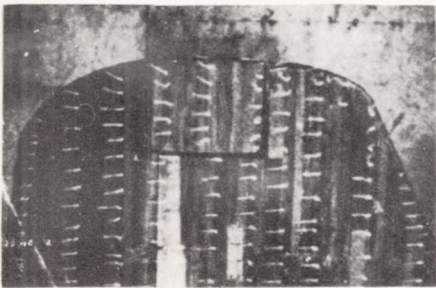
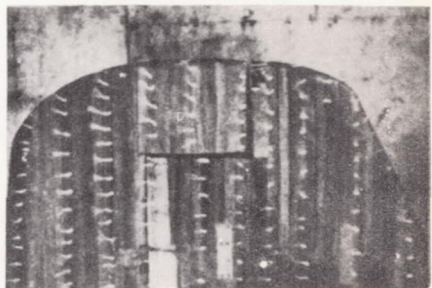
(a) $\alpha = 0^\circ$.(b) $\alpha = 4^\circ$.(c) $\alpha = 8^\circ$.(d) $\alpha = 12^\circ$.

Figure 18.- Tuft study over upper surface of 0.7-scale model of XF6F vertical tail with horn 2-d. Rudder neutral.

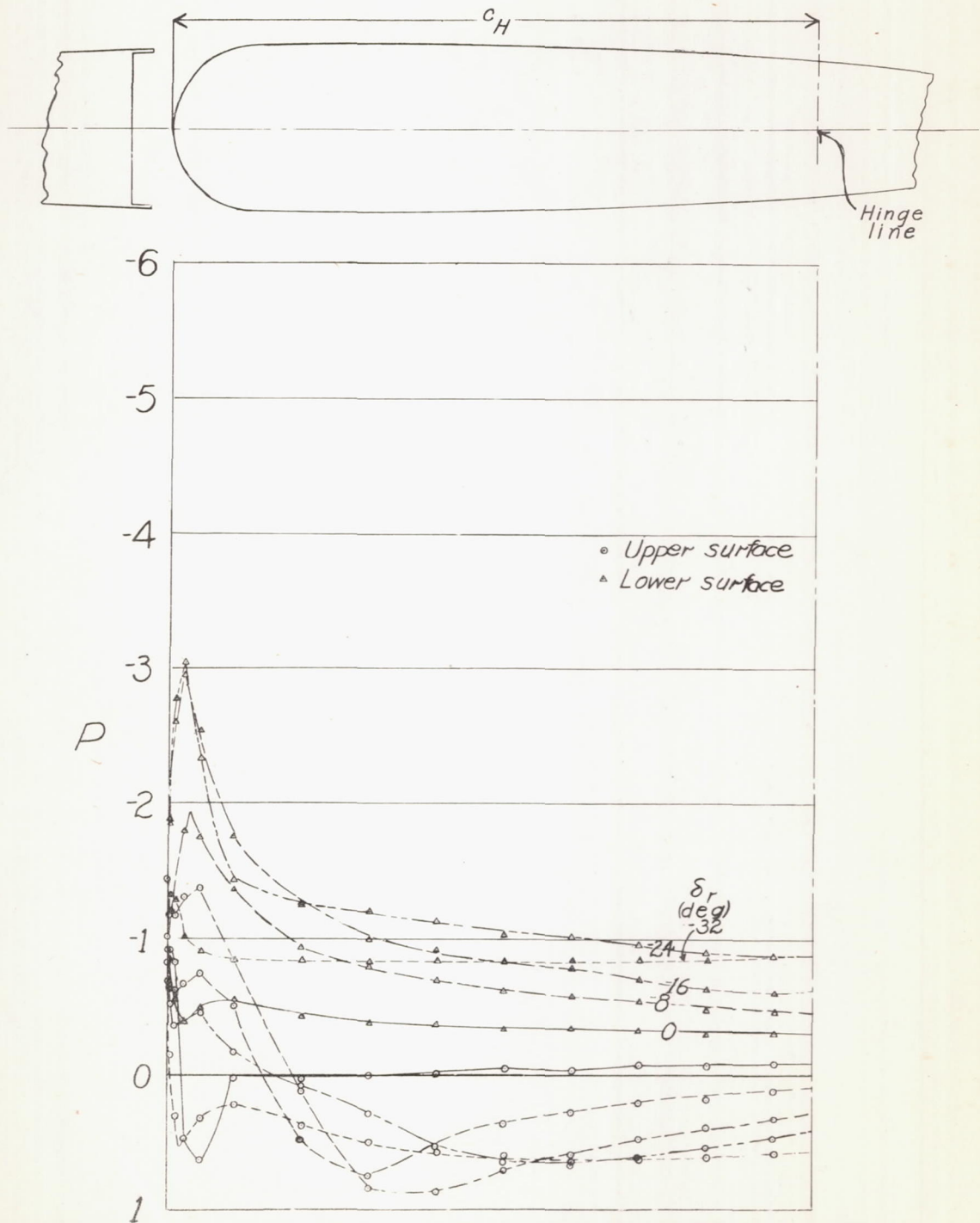


Figure 19.- Pressure distribution over horn 8-a on 0.7-scale model of XF6F vertical tail. $\alpha = -8^\circ$.

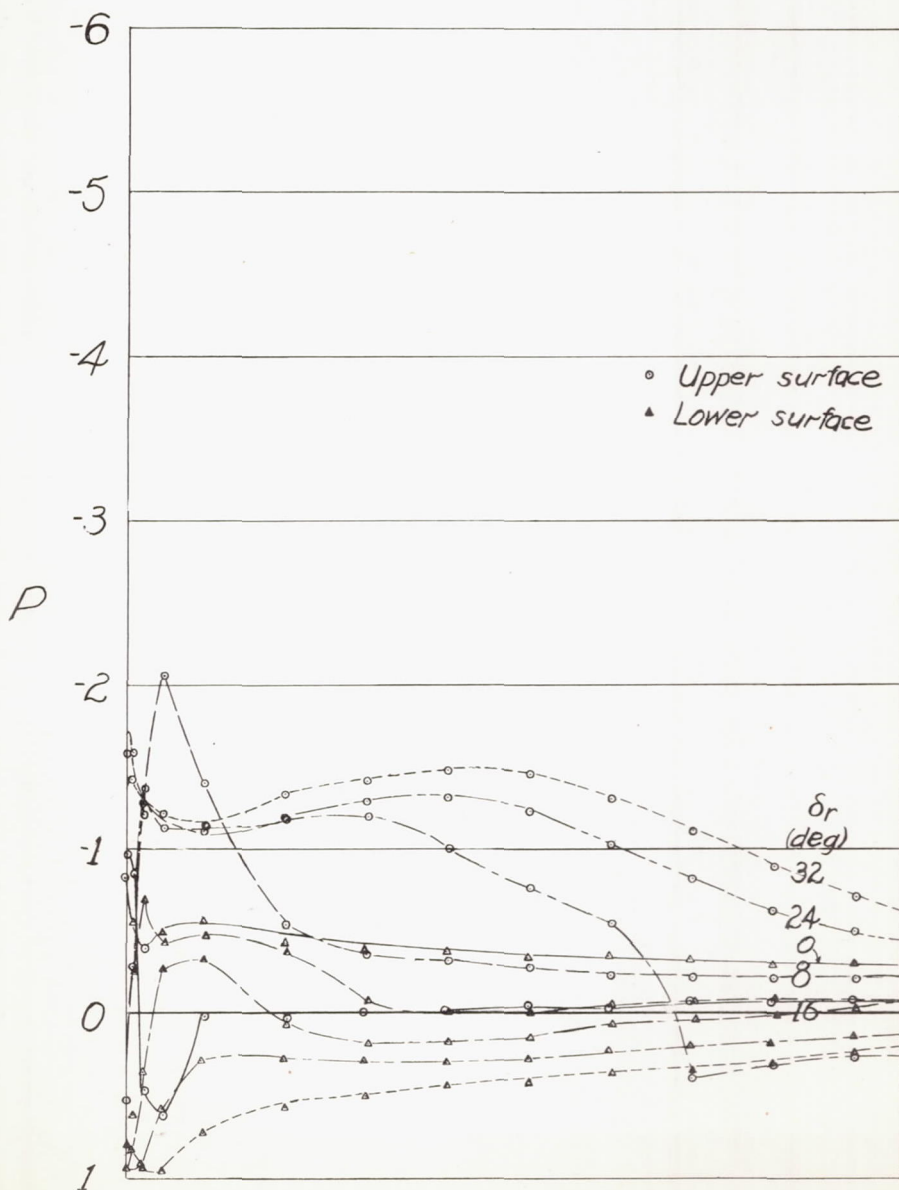
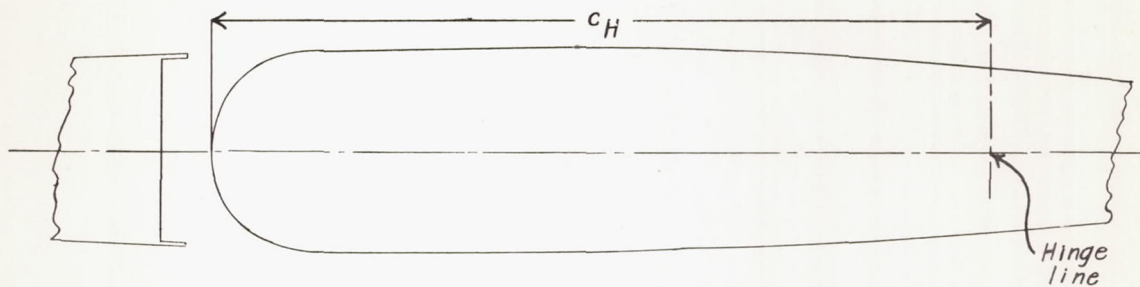


Figure 19.- Concluded.

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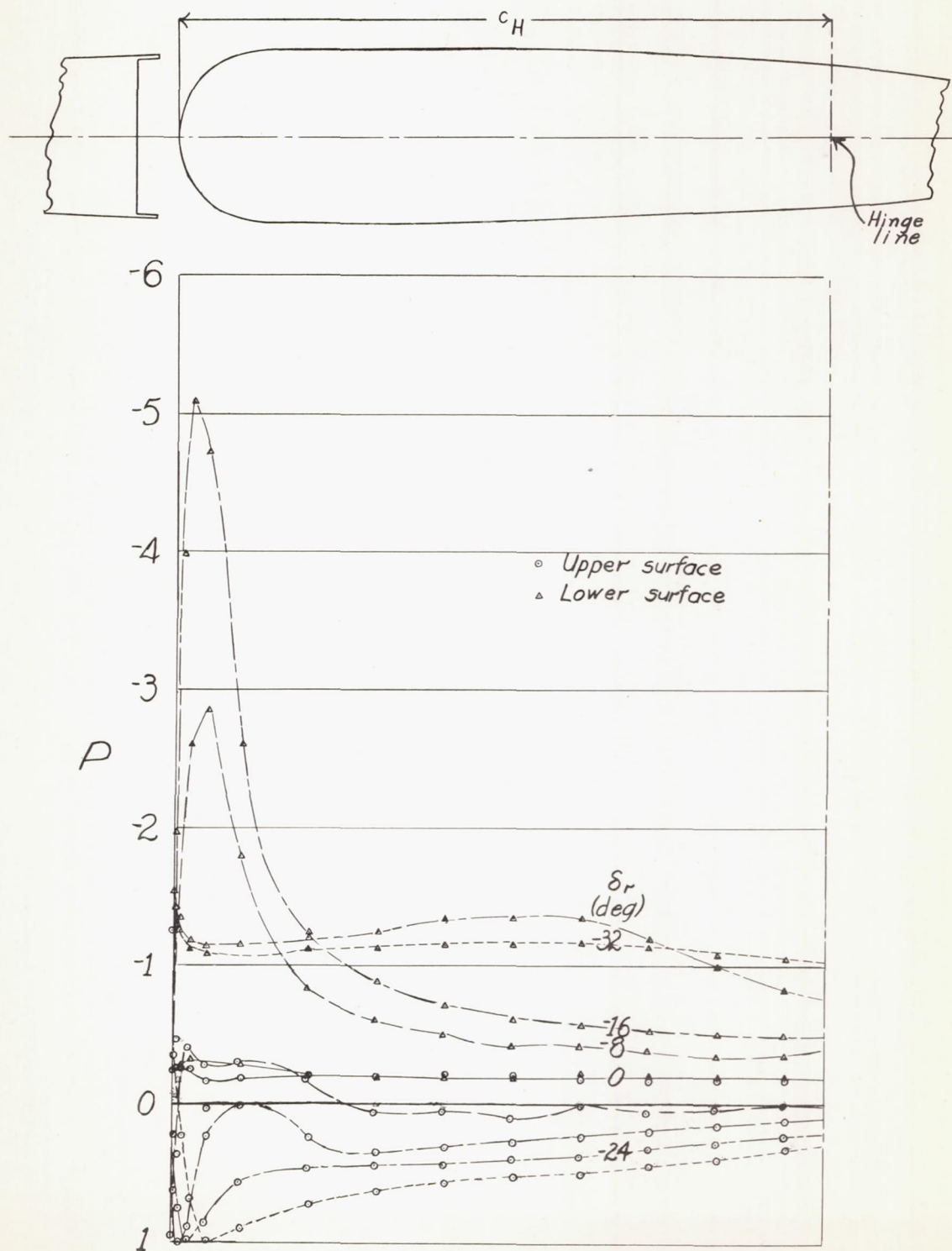


Figure 20.- Pressure distribution over horn 8-a on 0.7-scale model of XF6F vertical tail. $\alpha = 0^\circ$.

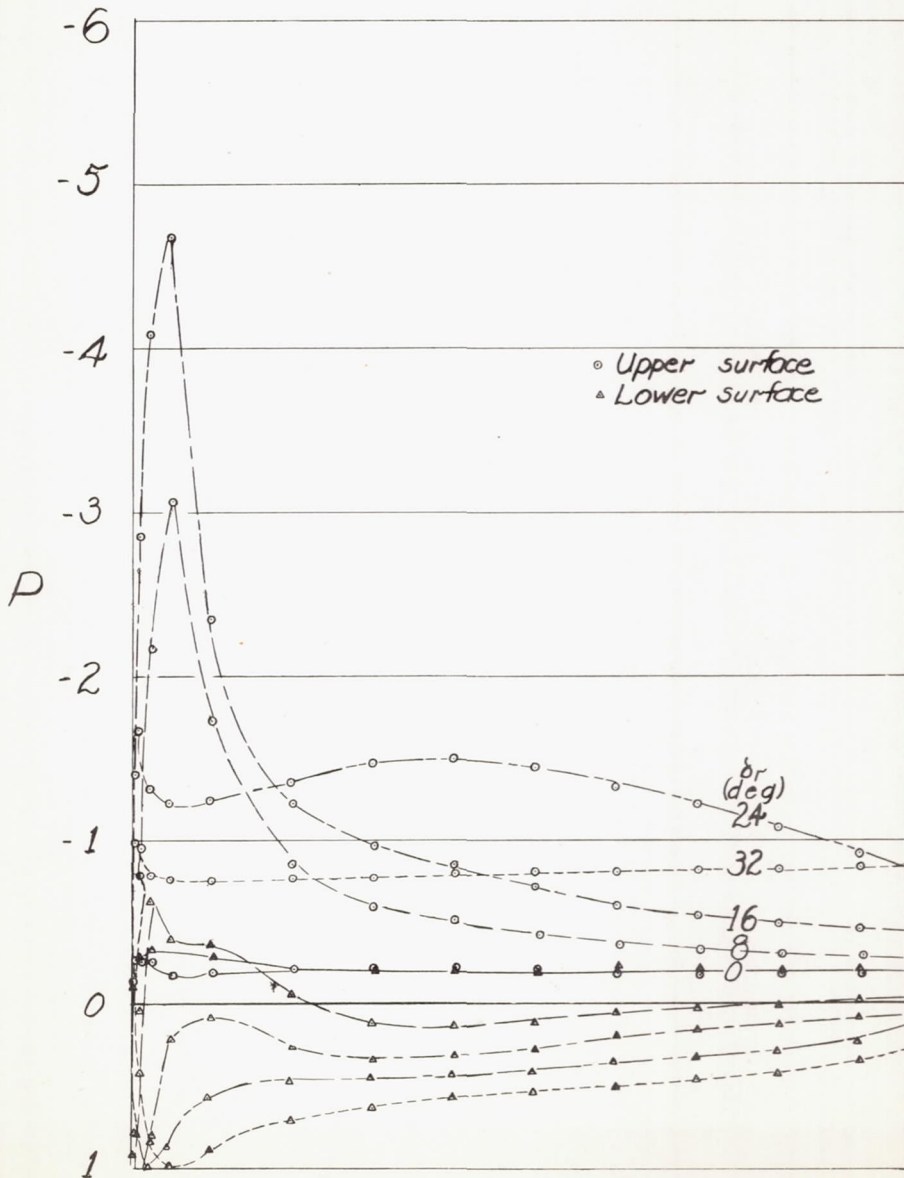
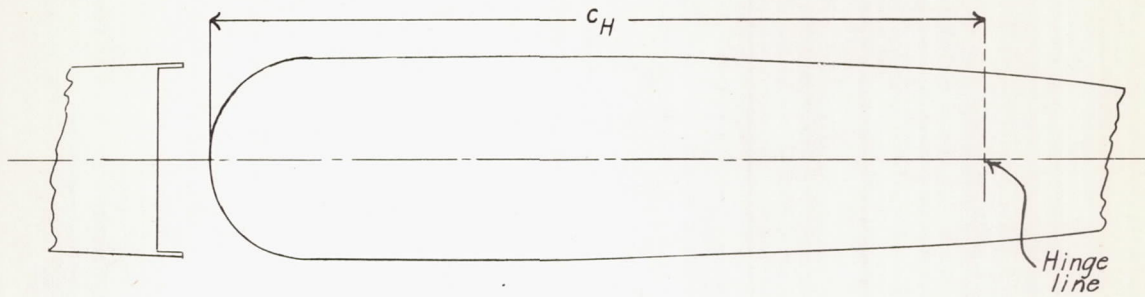


Figure 20.- Concluded.

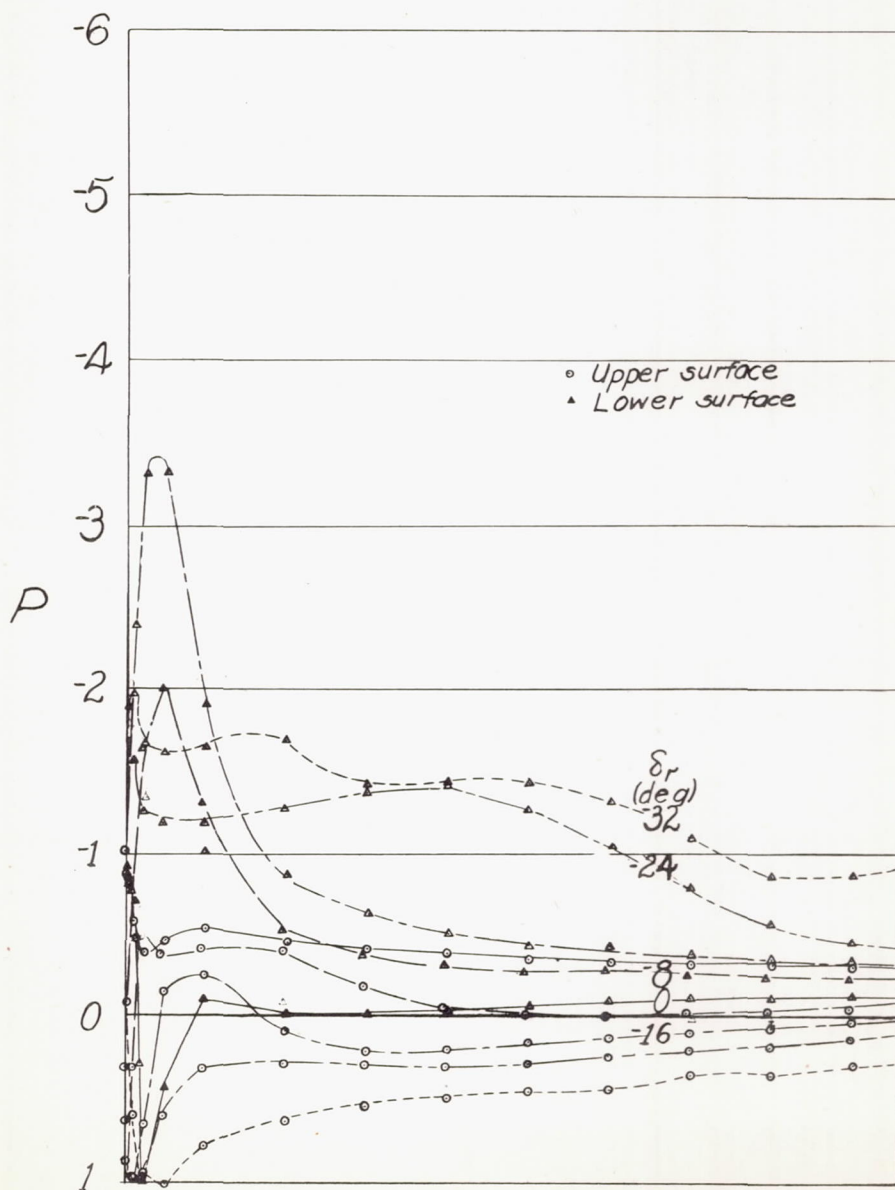
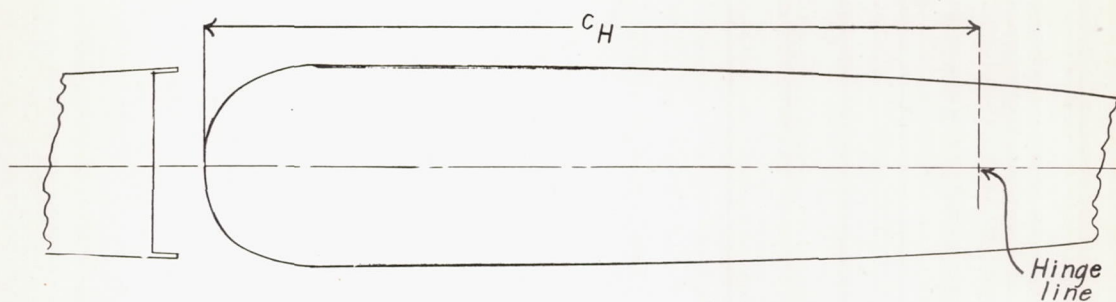


Figure 21.- Pressure distribution over horn 8-0 on 0.7-scale model of XF6F vertical tail, $\alpha = 8^\circ$.

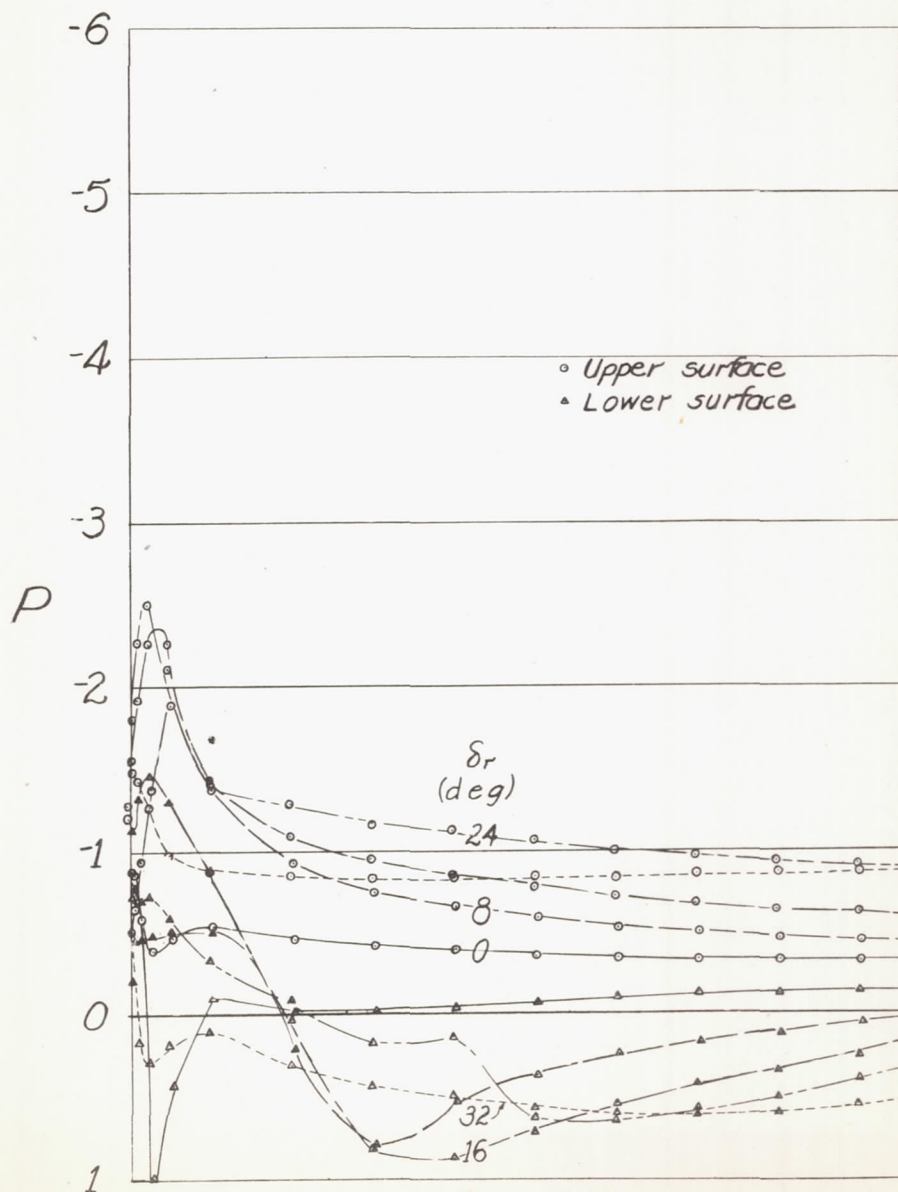
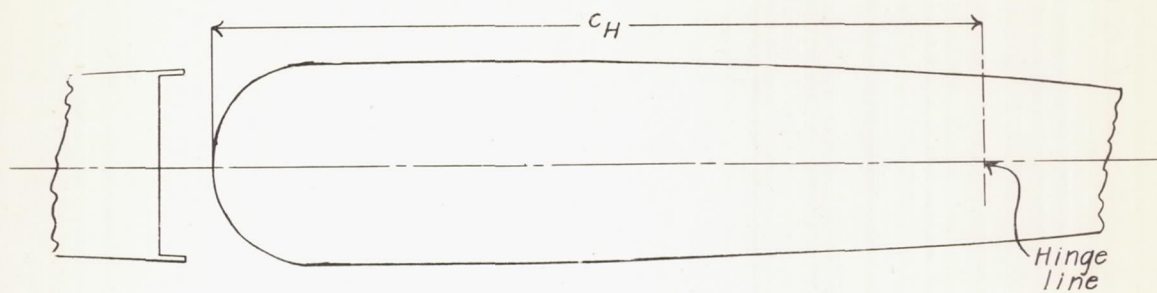


Figure 21.- Concluded

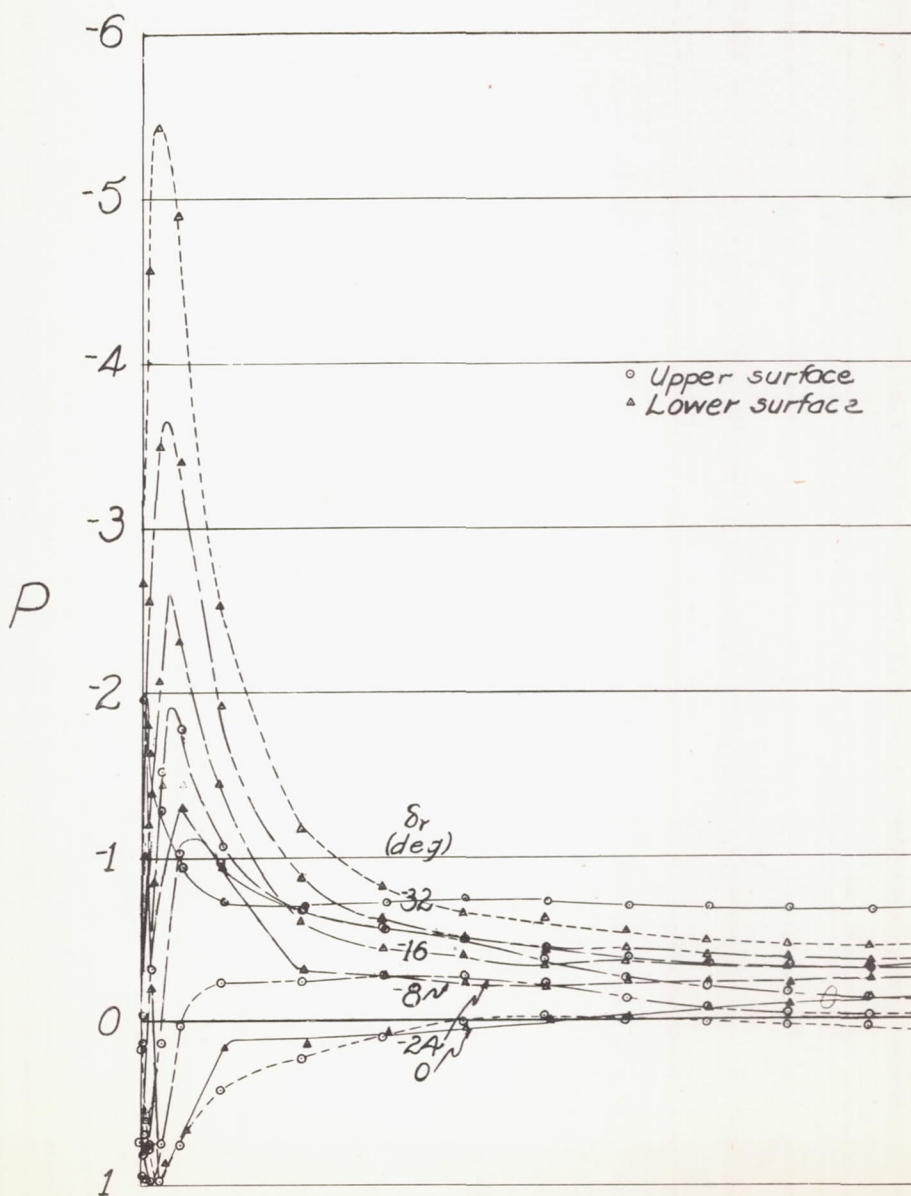
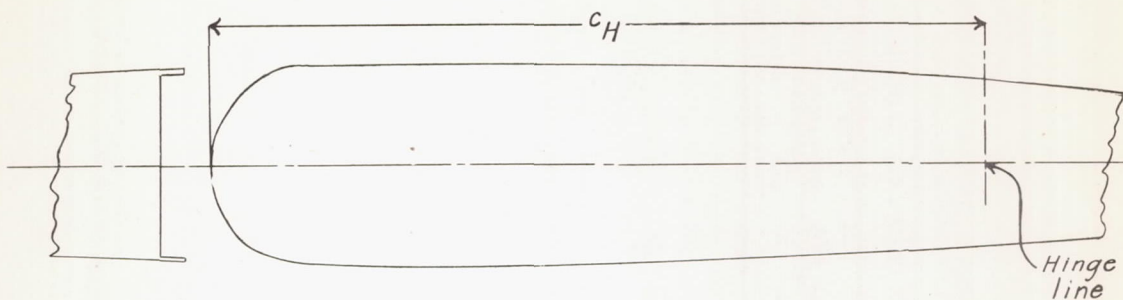


Figure 22.- Pressure distribution over horn 8-0 on 0.7-scale model of XF6F vertical tail. $\alpha = 16^\circ$.

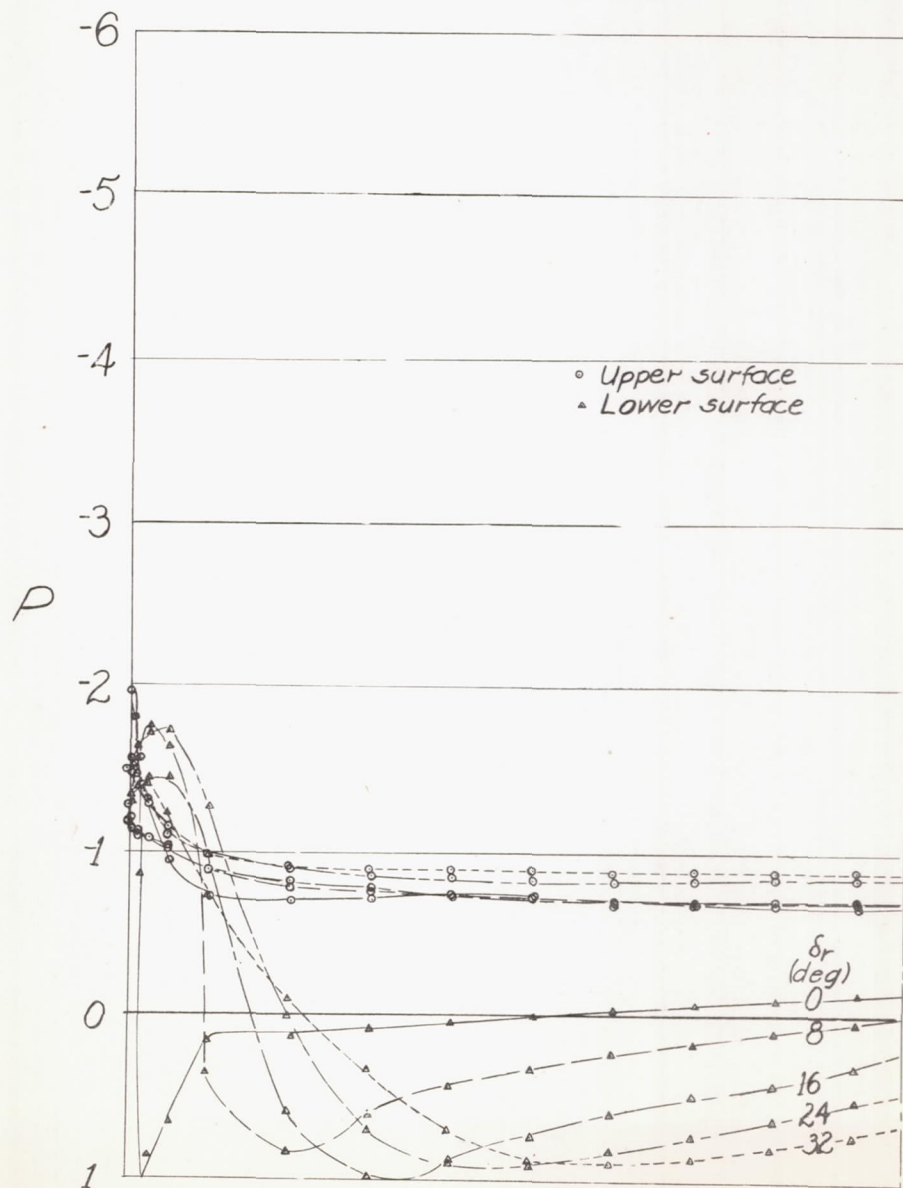
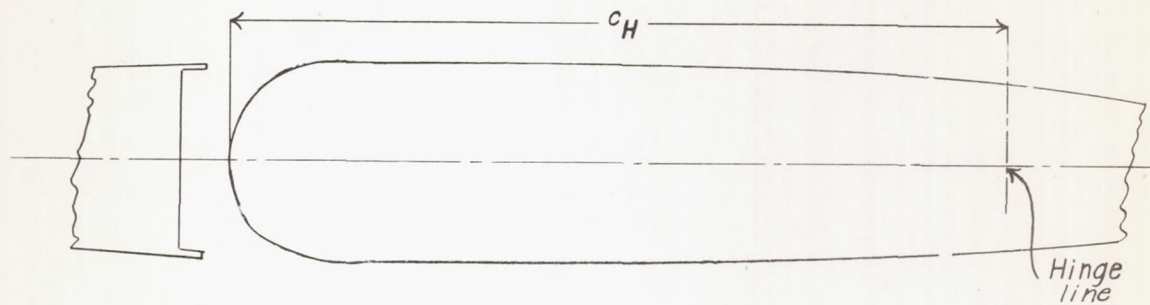
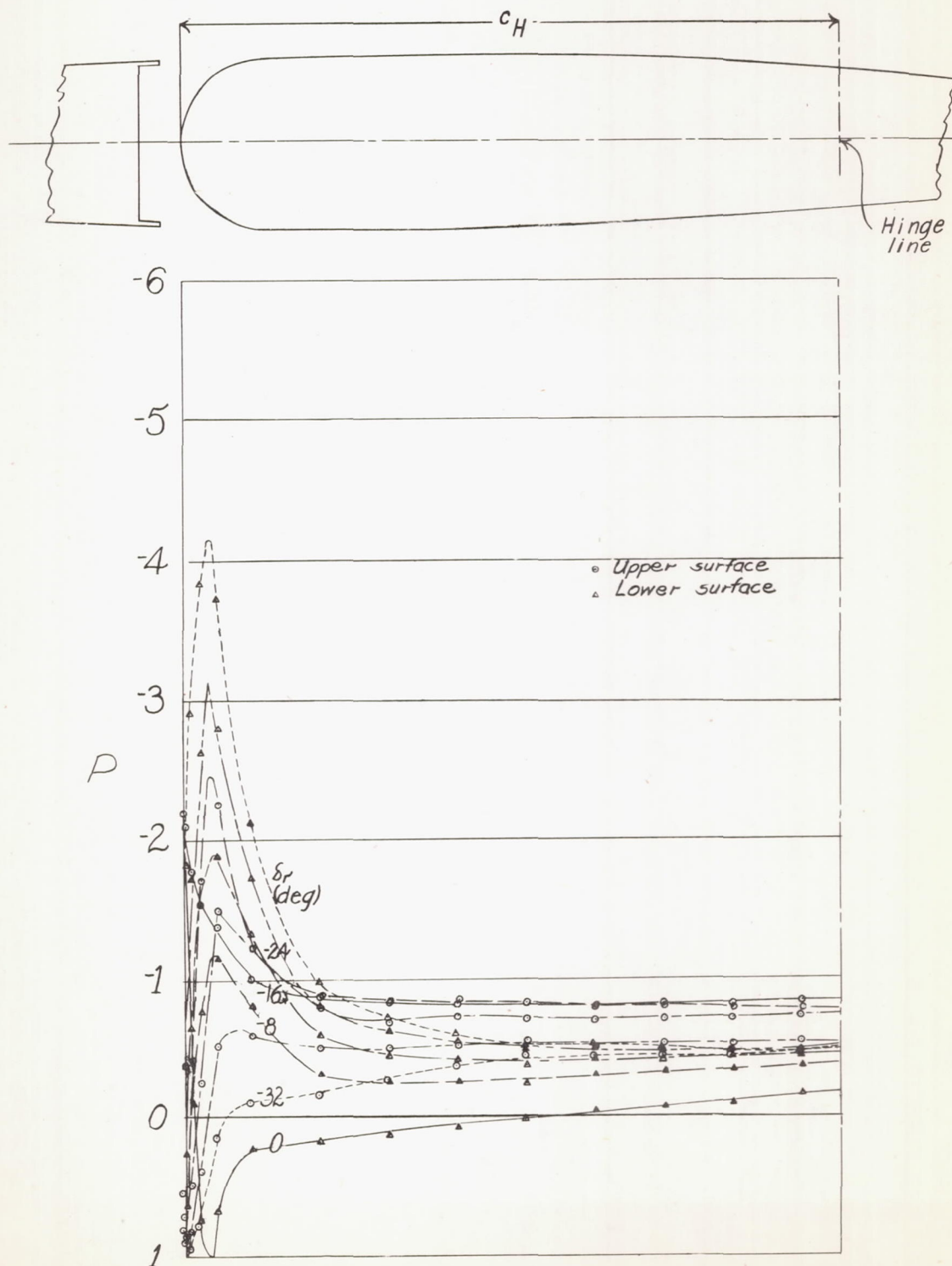


Figure 22.- Concluded.



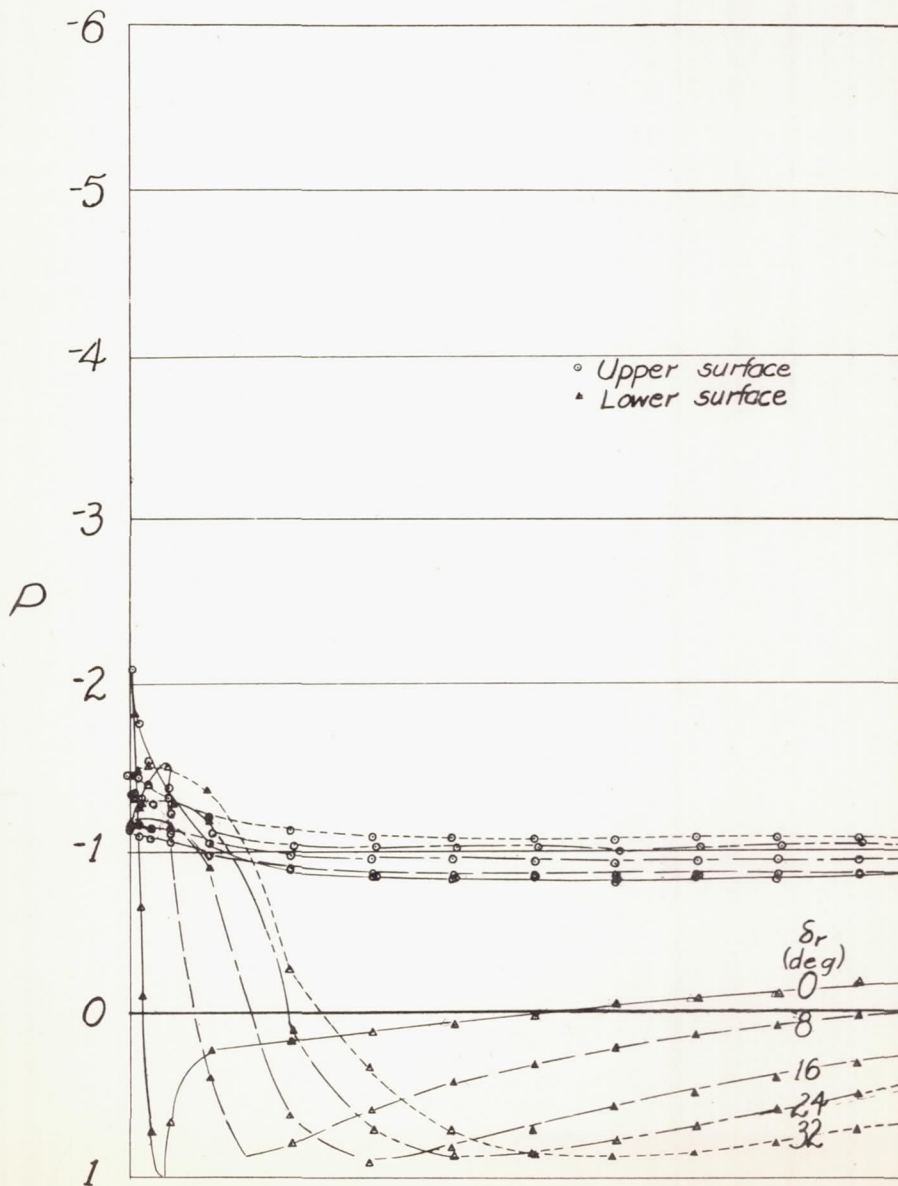
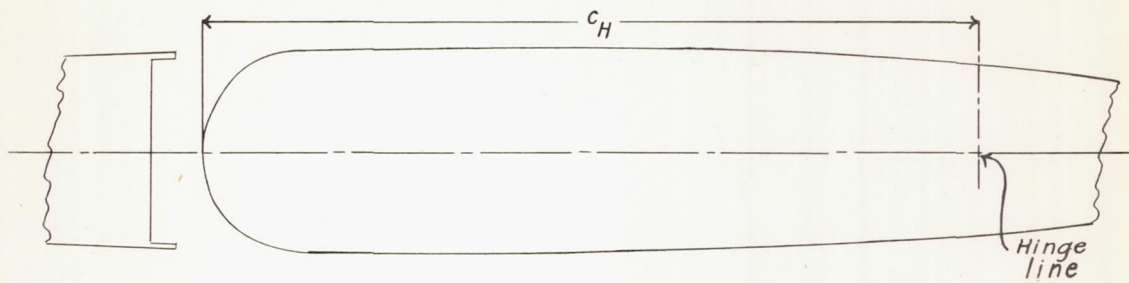


Figure 23.- Concluded.

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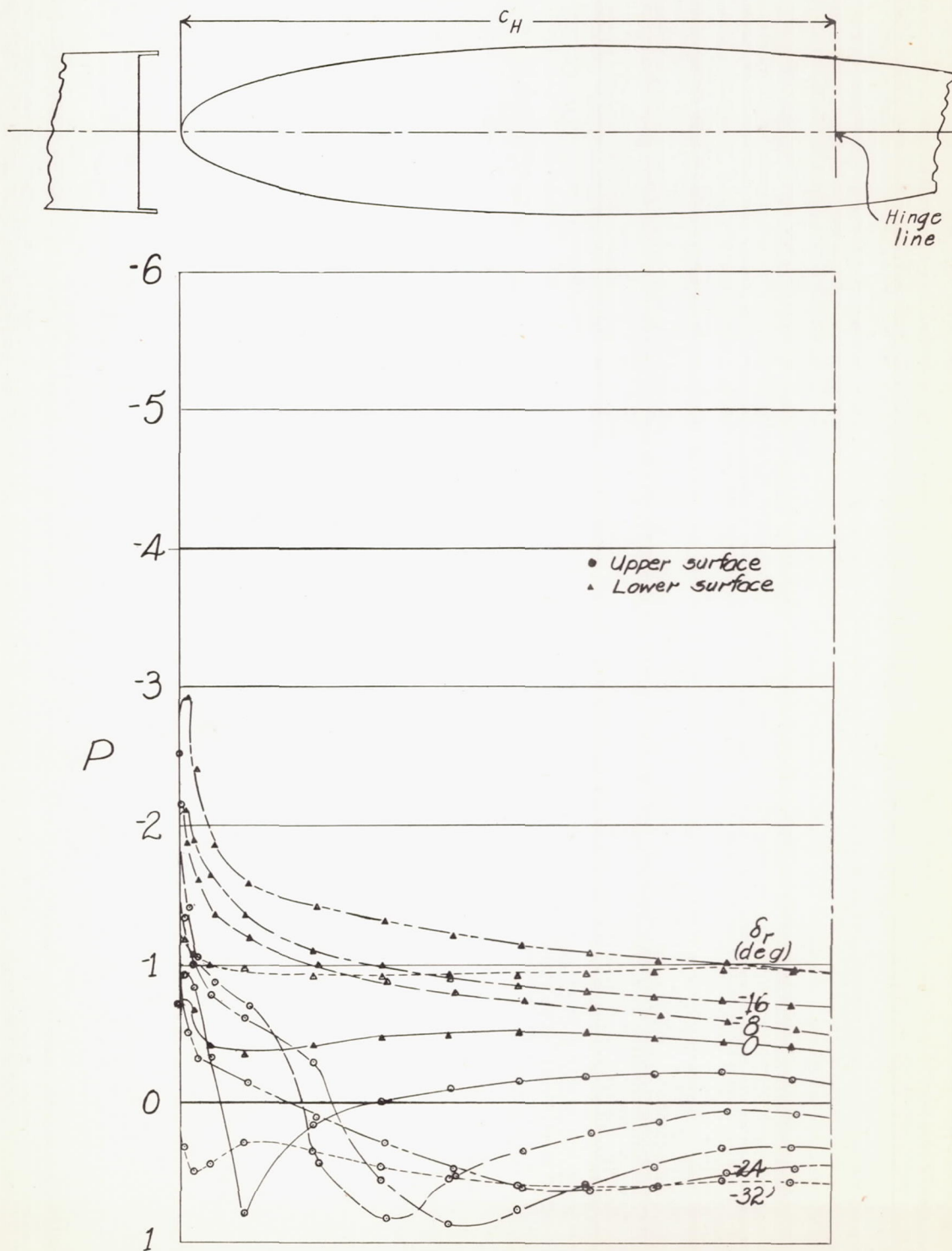


Figure 24.- Pressure distribution over horn 8-b on 0.7-scale model of XF6F vertical tail surface. $\alpha = -8^\circ$.

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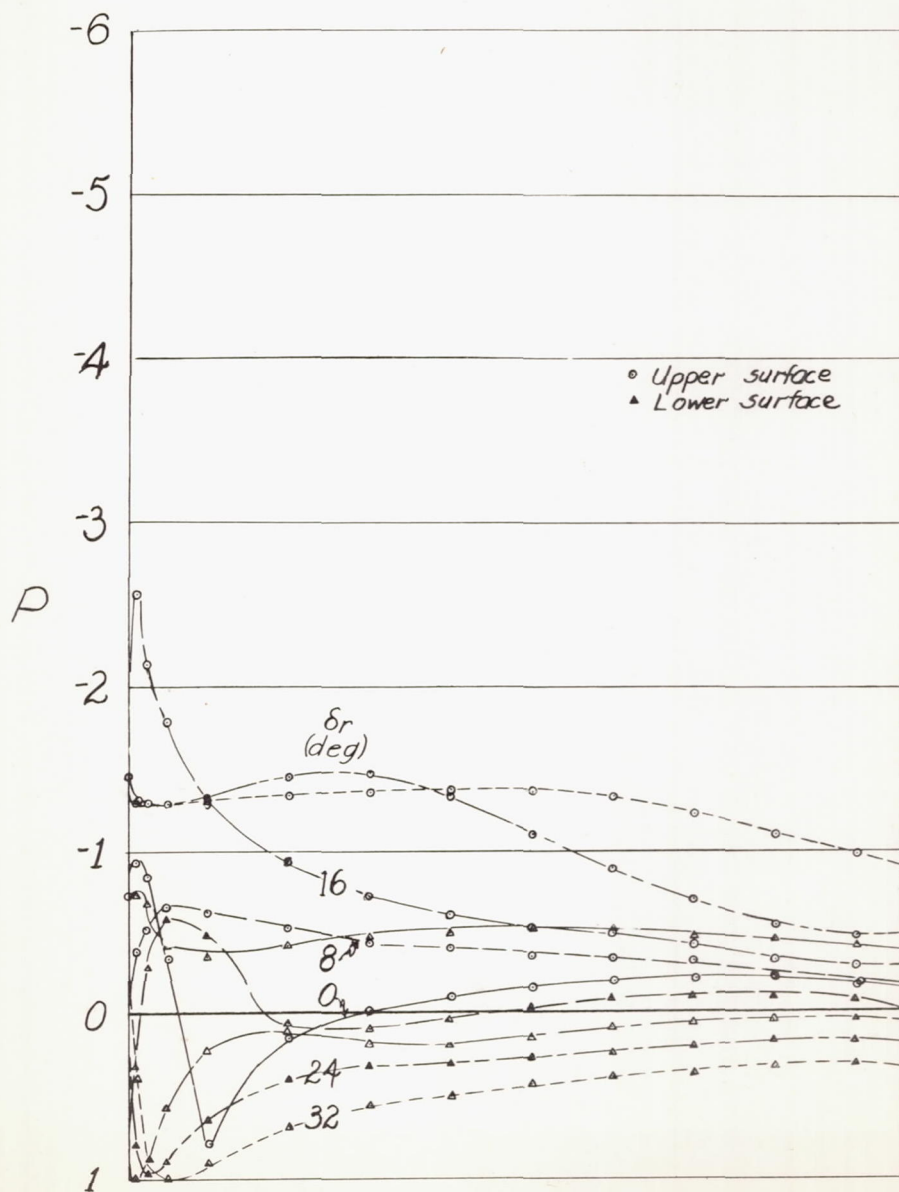
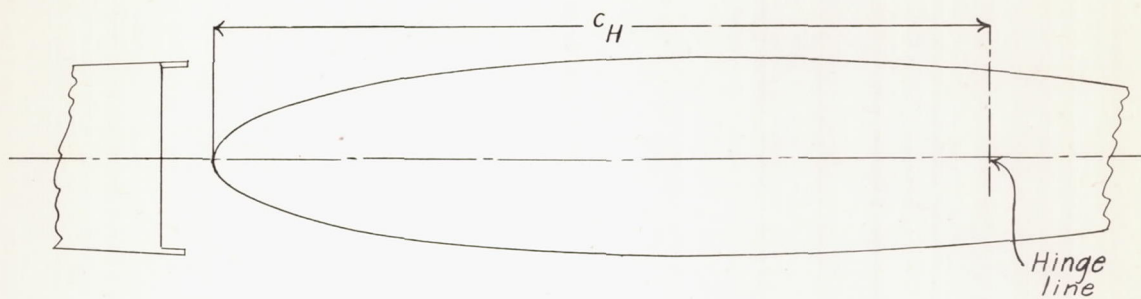


Figure 24.- Concluded.

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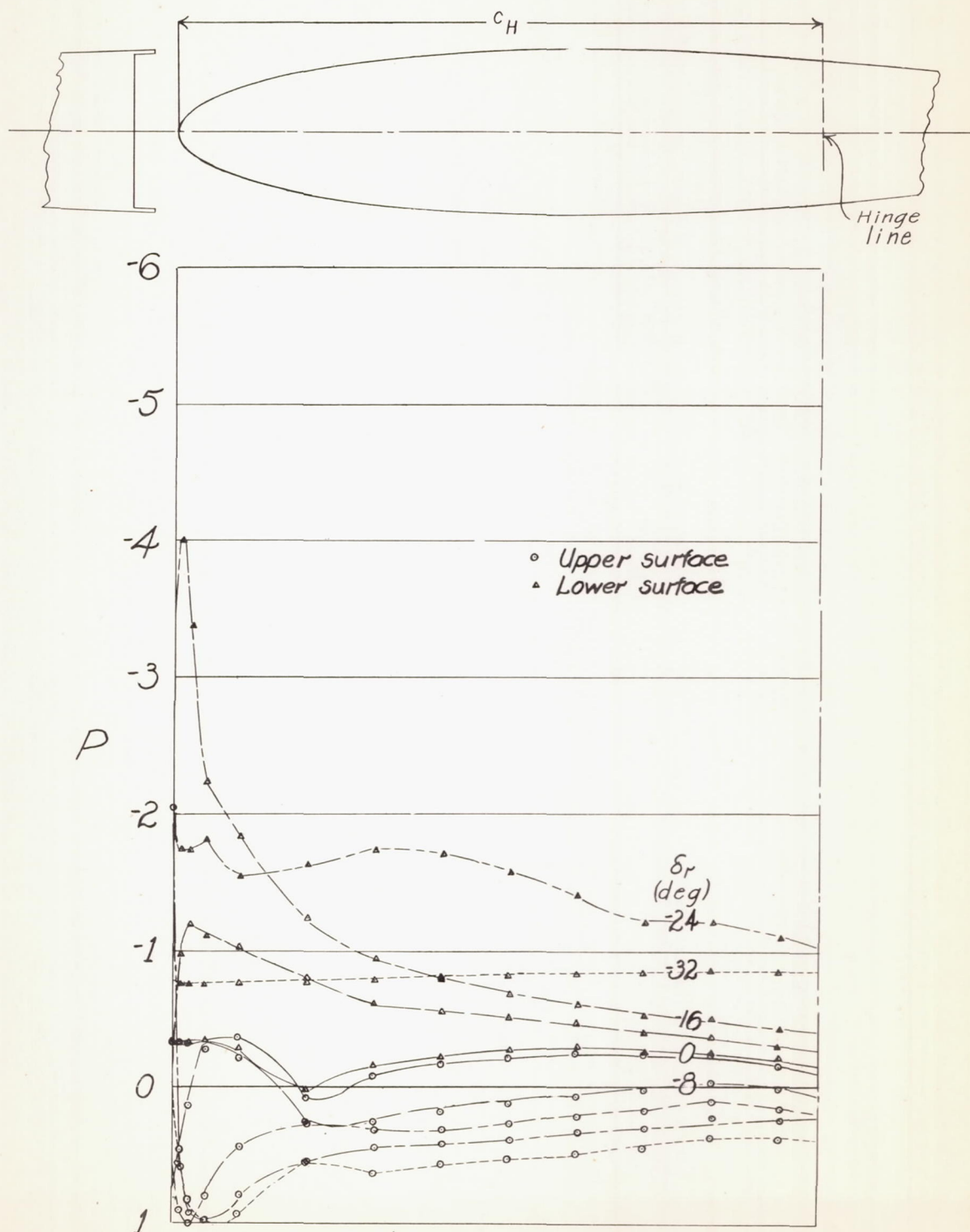


Figure 25- Pressure distribution over horn 8-b on 0.7-scale model of XF6F vertical tail. $\alpha = 0^\circ$.

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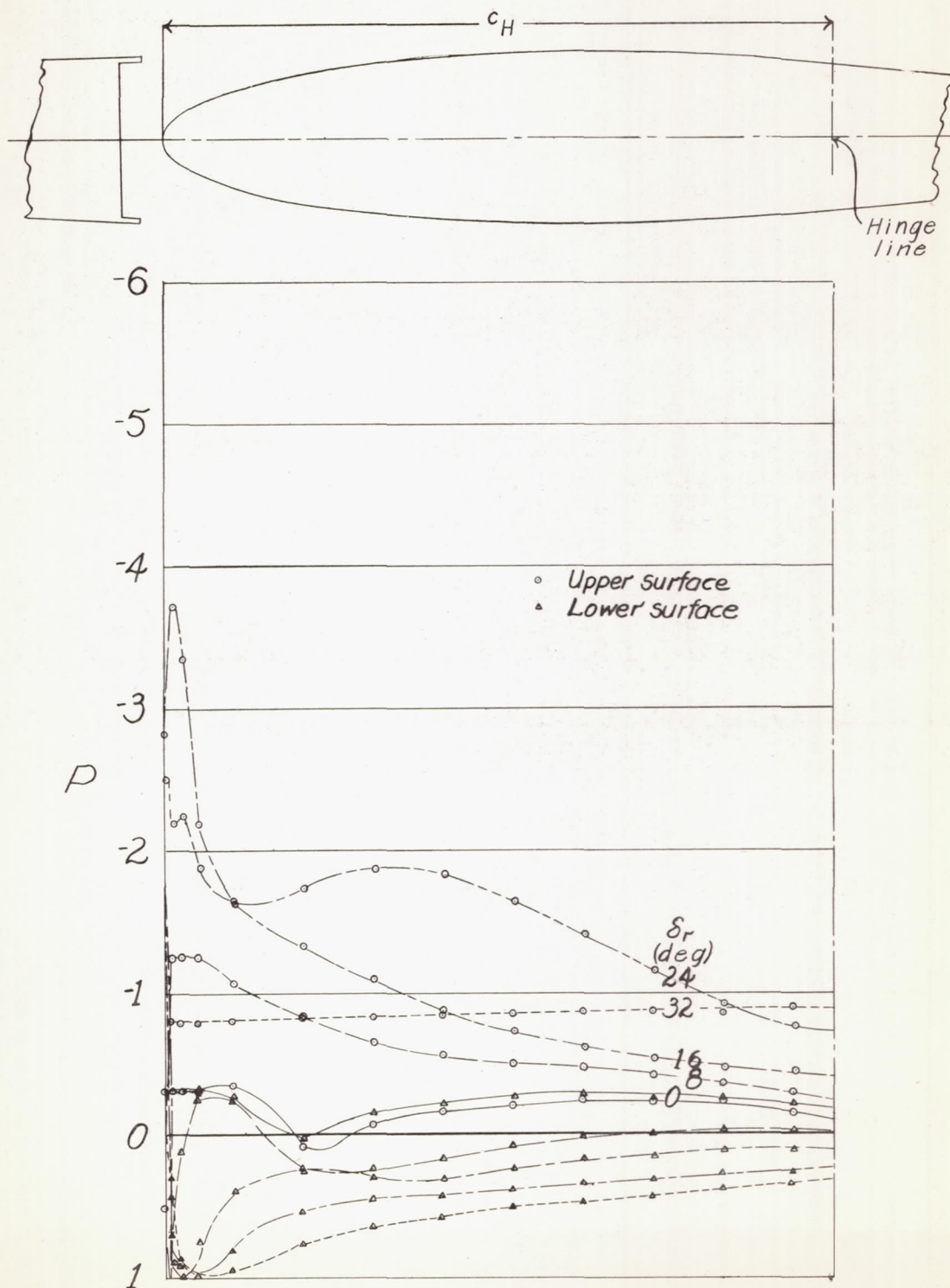


Figure 25.- Concluded.

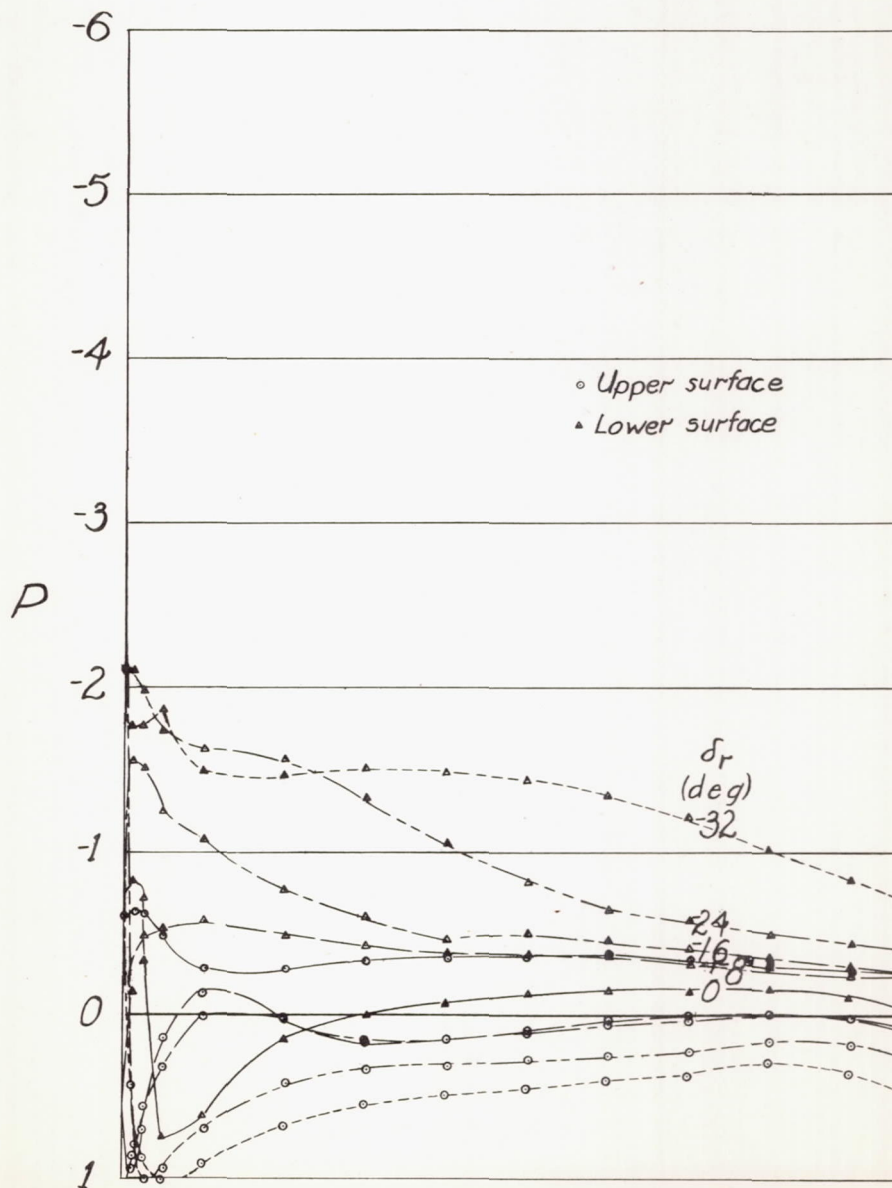
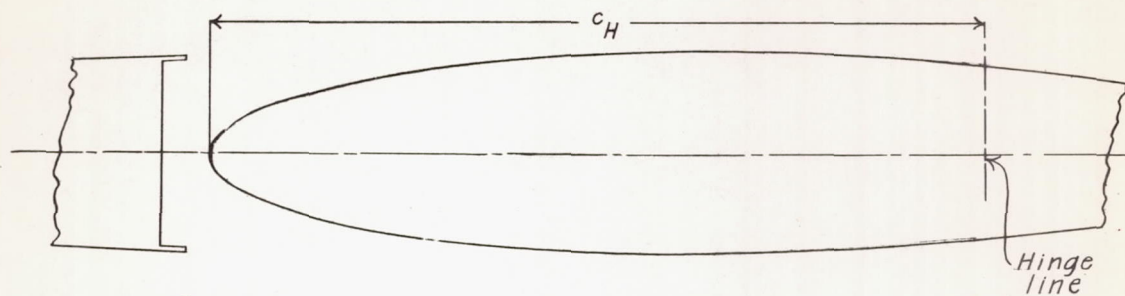


Figure 26.-Pressure distribution over horn 8-b on 07-scale model of XF6F vertical tail surface. $\alpha = 8^\circ$.

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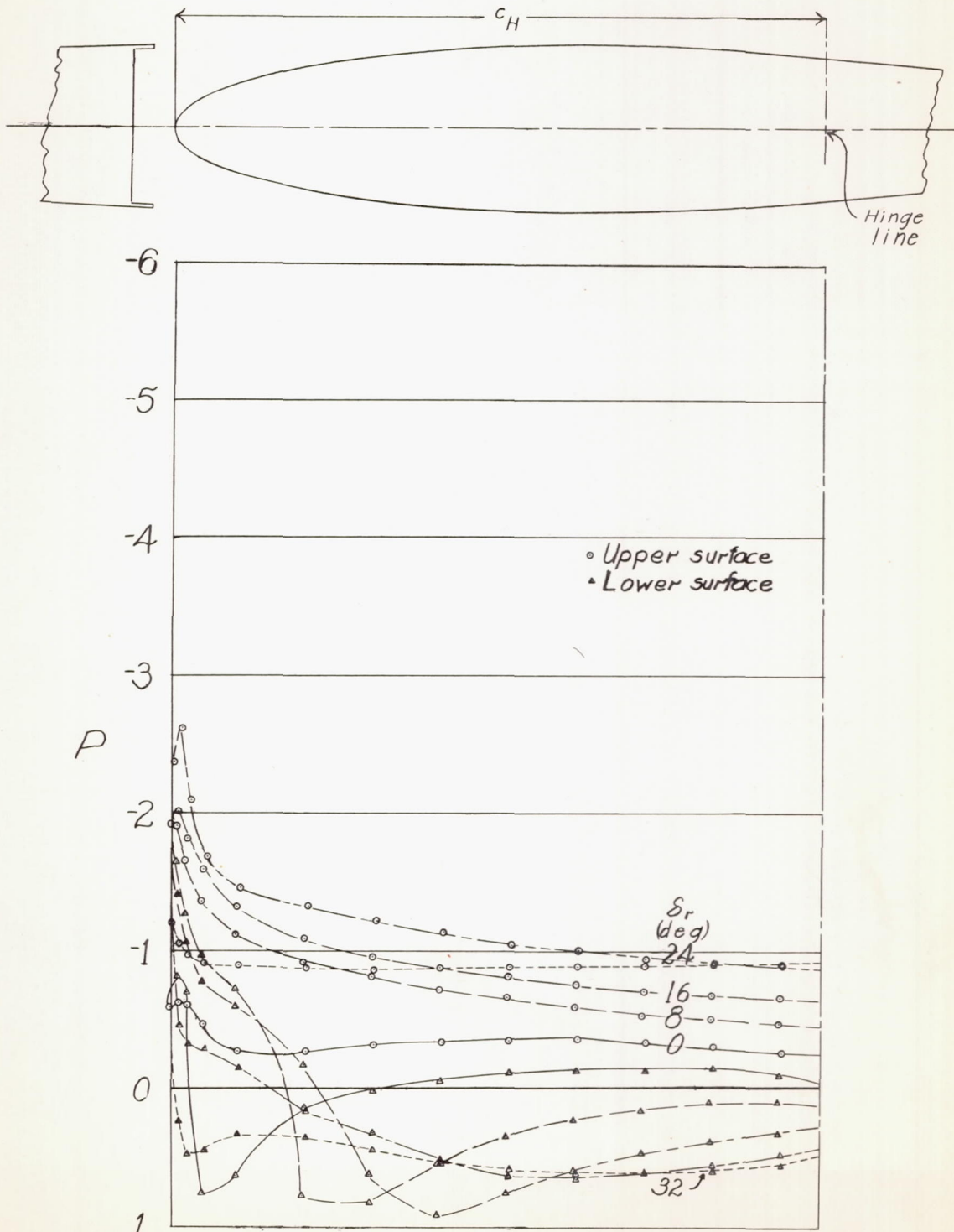


Figure 26.- Concluded.

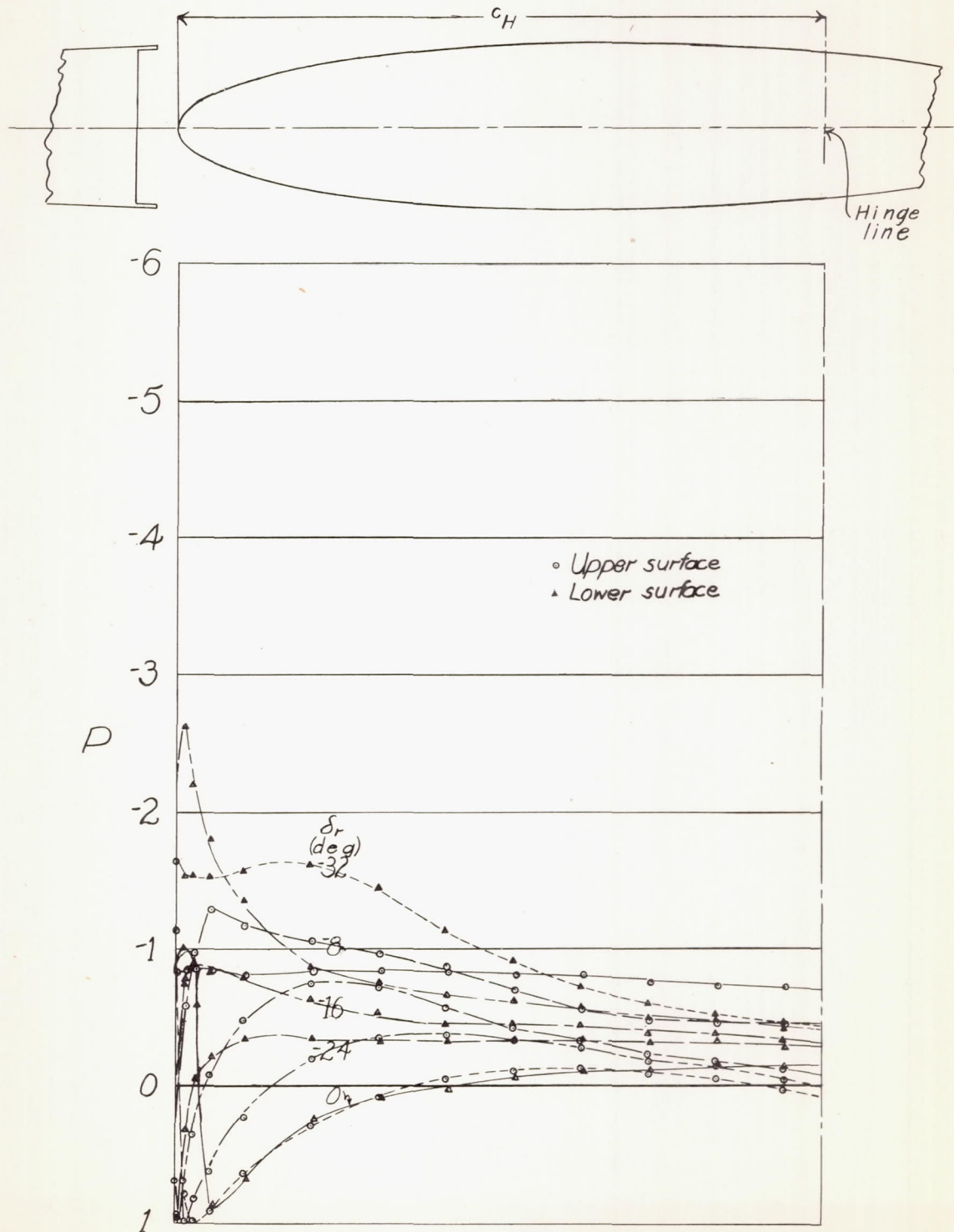


Figure 27.- Pressure distribution over horn 8-b on 0.7-scale model of XF6F vertical tail surface. $\alpha = 16^\circ$.

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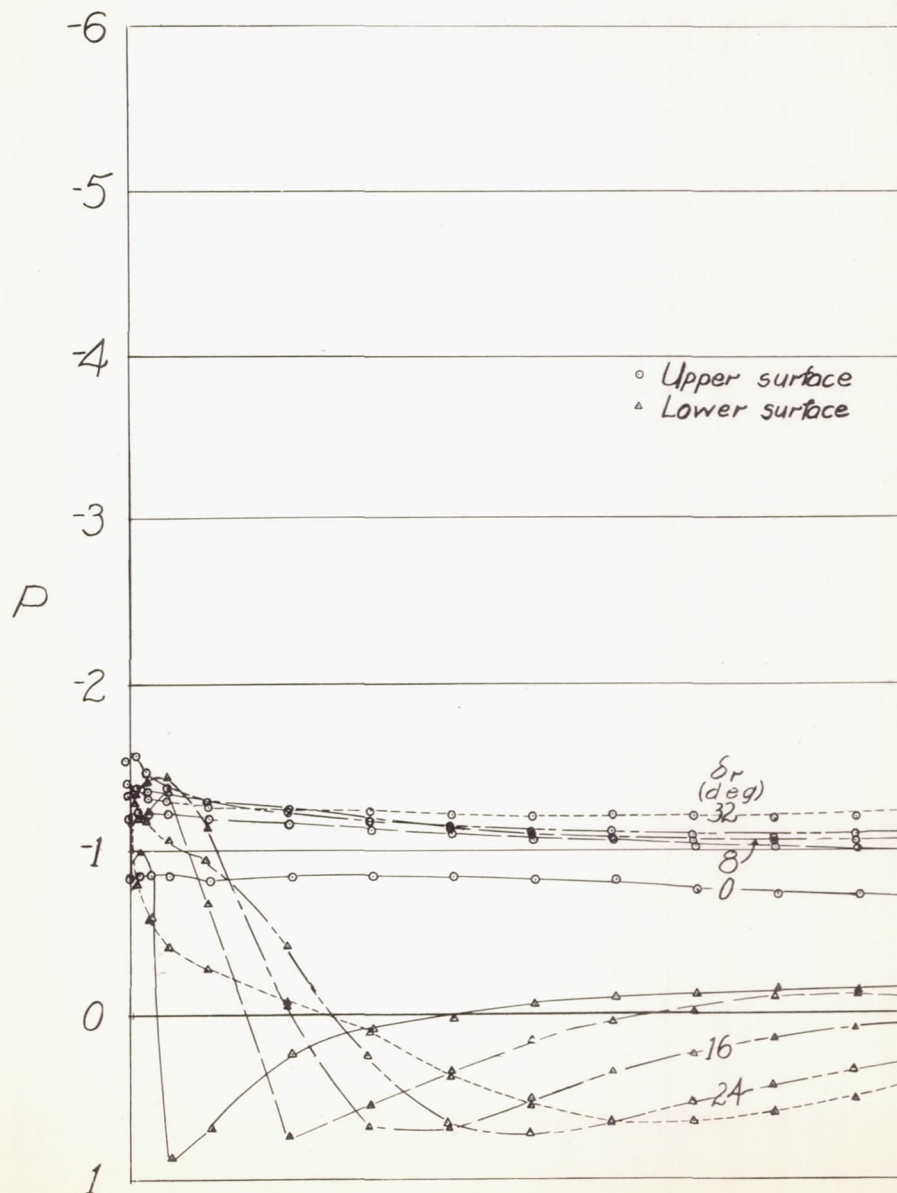
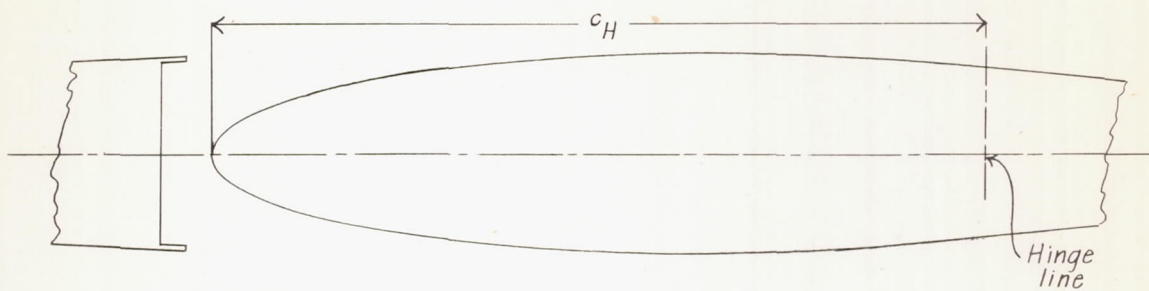


Figure 27:- Concluded.

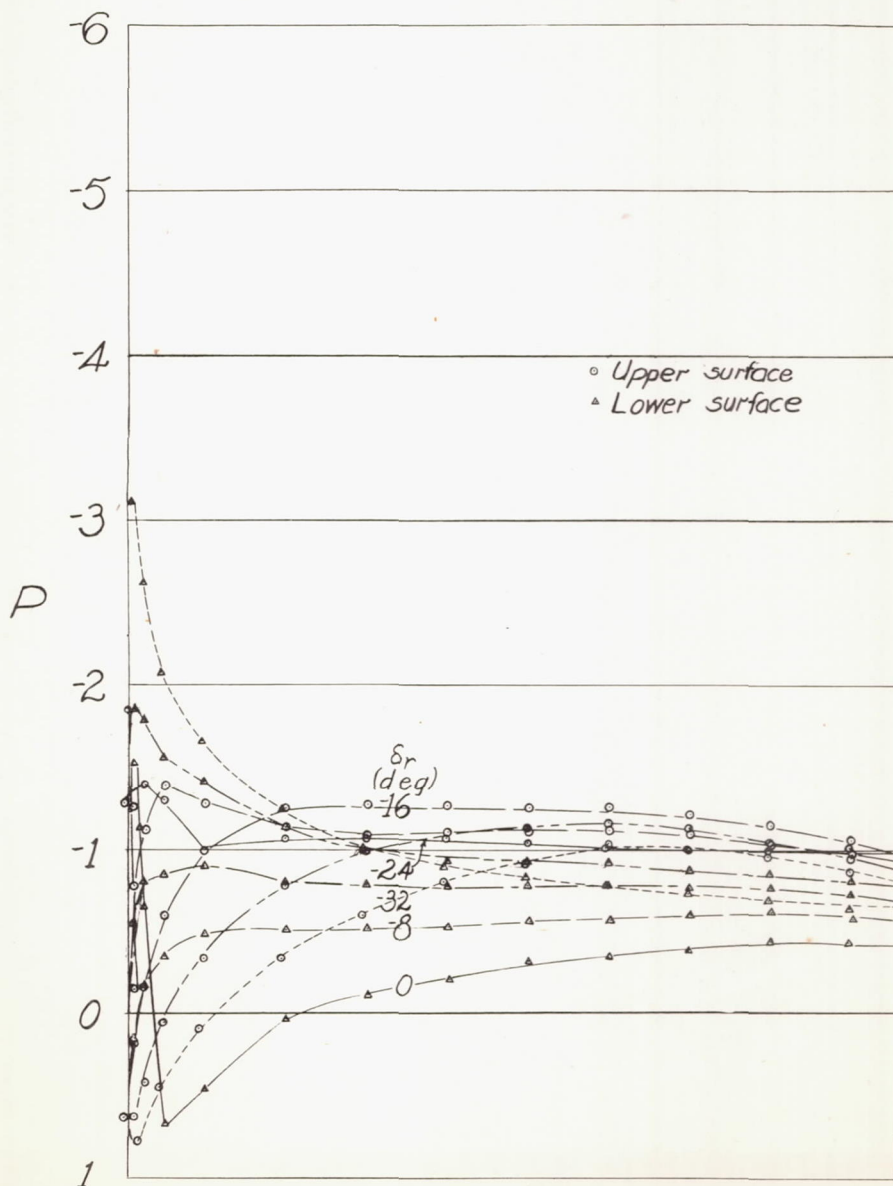
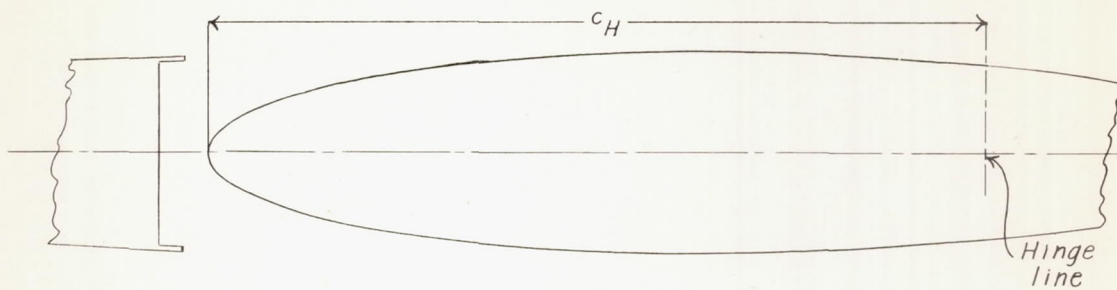


Figure 28.- Pressure distribution over horn 8-b on 0.7-scale model of XF6F vertical tail surface. $\alpha = 24^\circ$

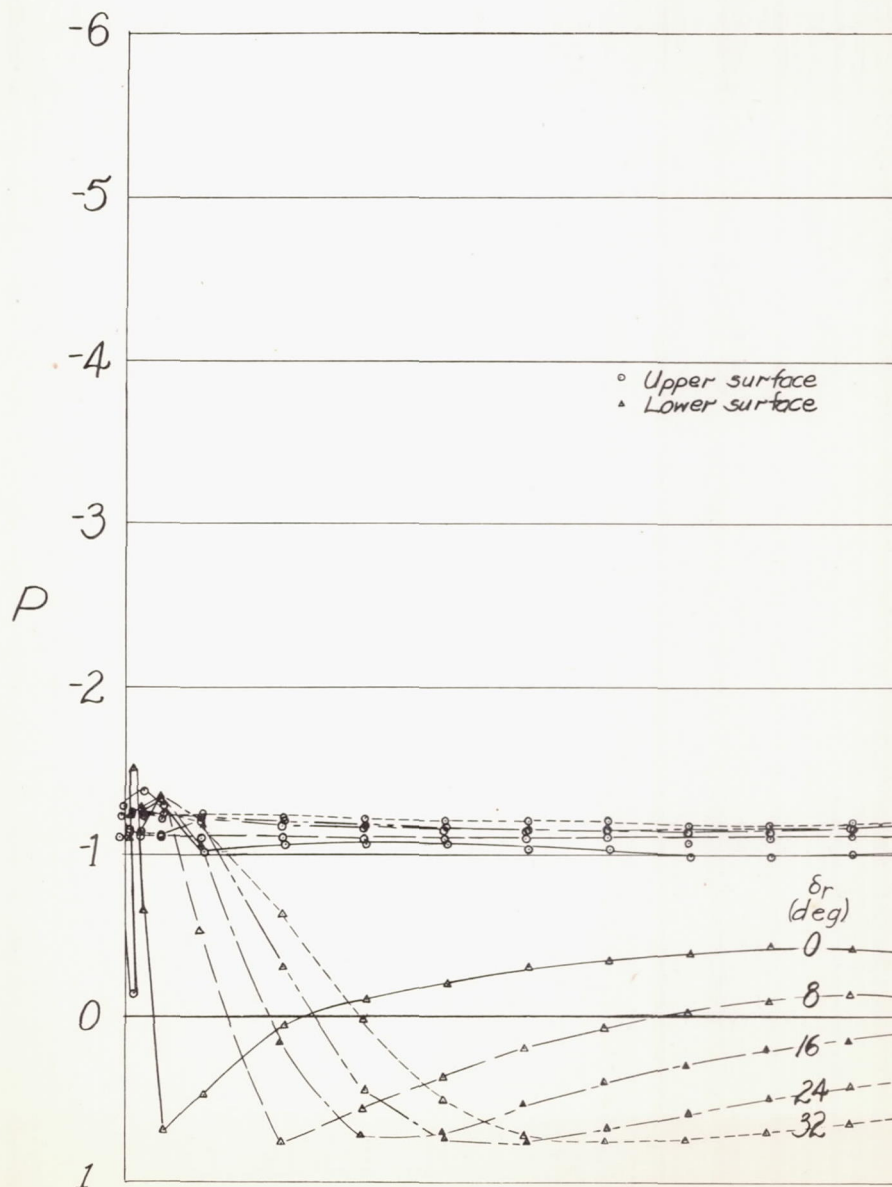
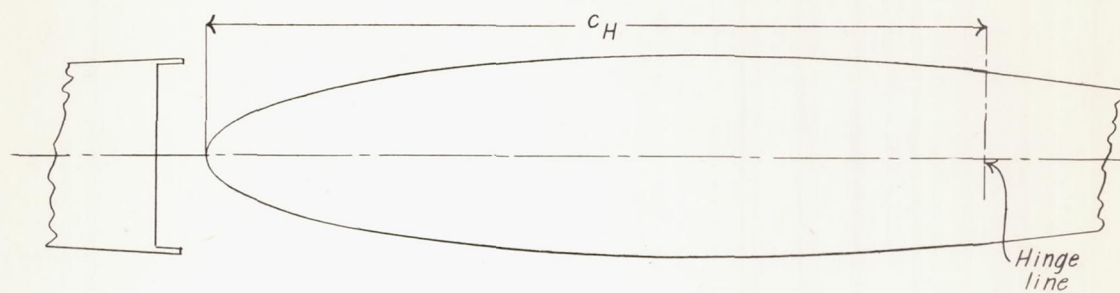


Figure 28.- Concluded.

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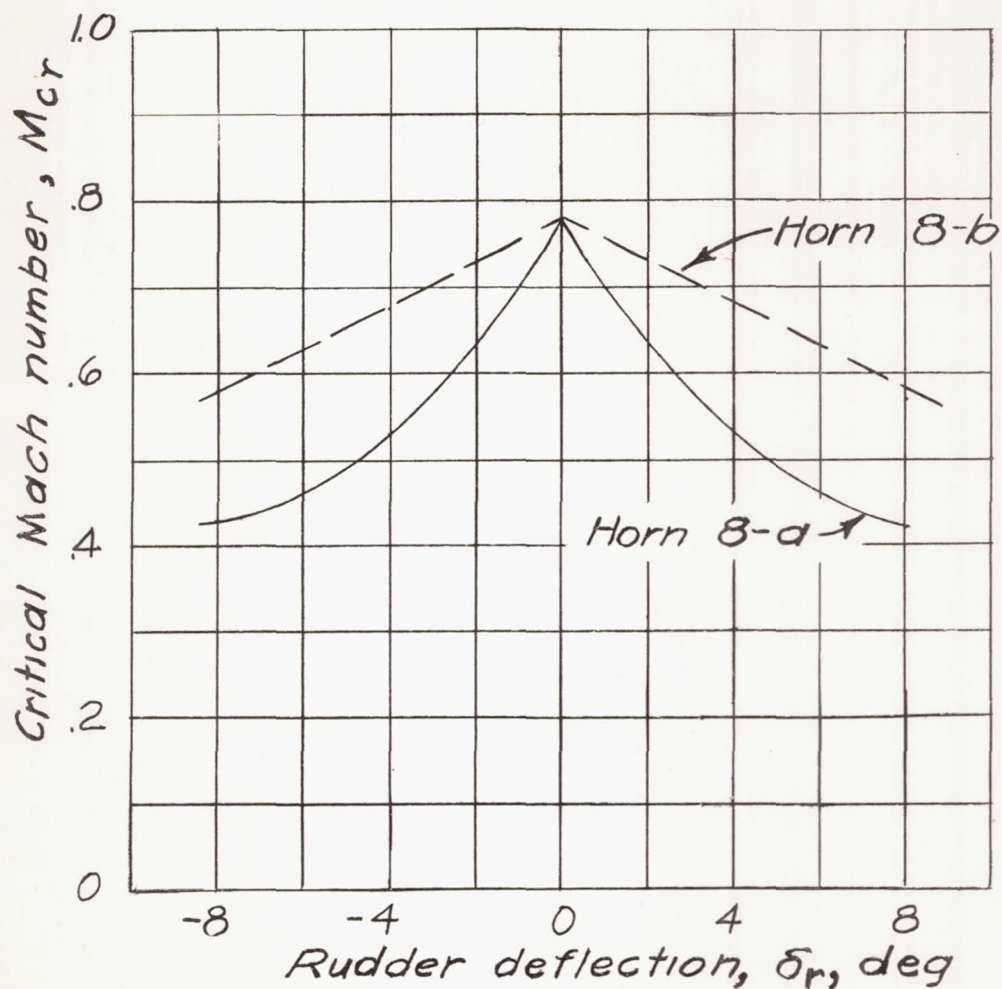


Figure 29.- Variation of critical Mach number with rudder deflection for two shielded horns on 0.7-scale model of XF6F vertical tail surface. $\alpha = 0^\circ$.

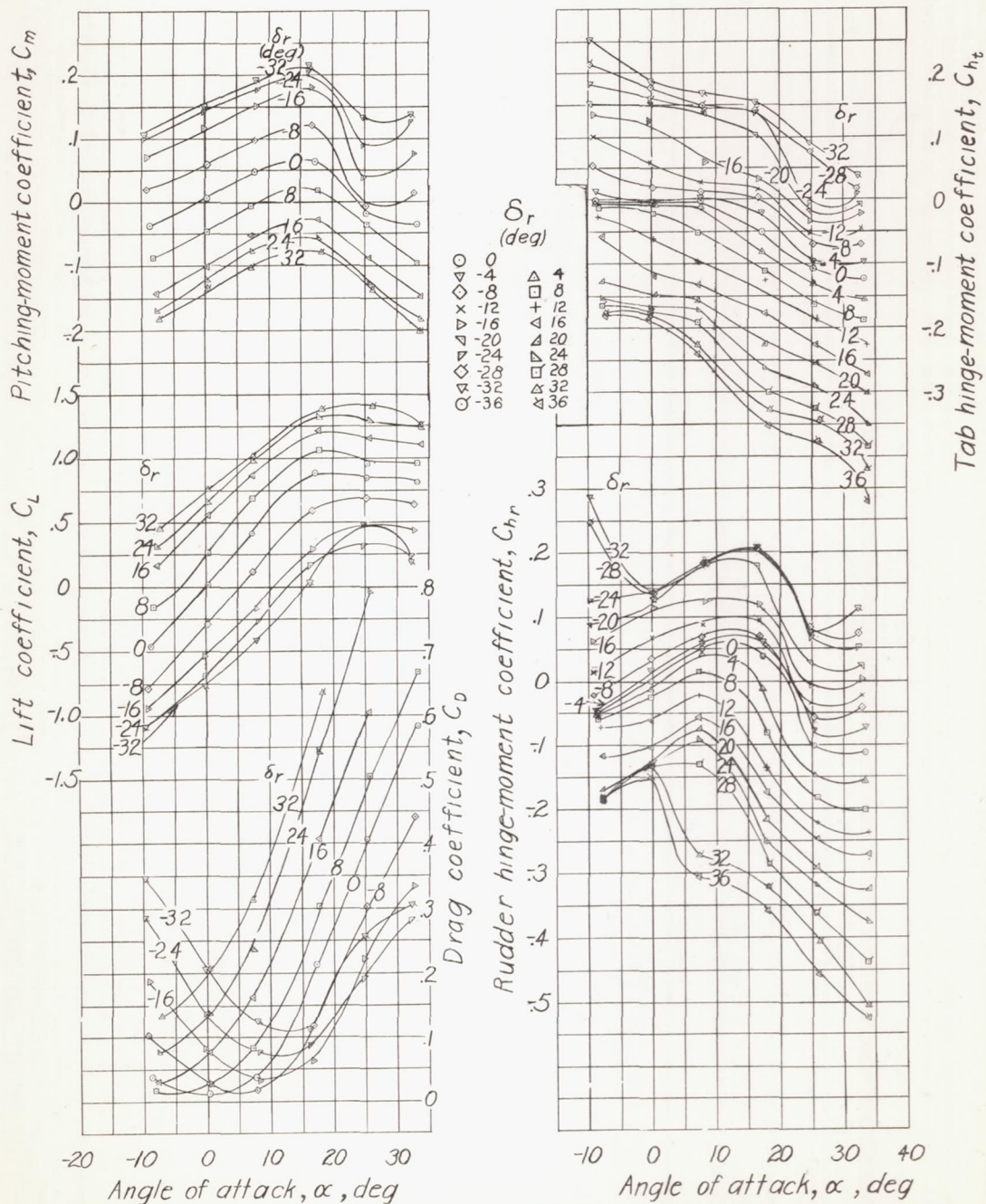


Figure 30. Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface with unshielded horn. Rudder gap sealed. $\delta_t = 0^\circ$.

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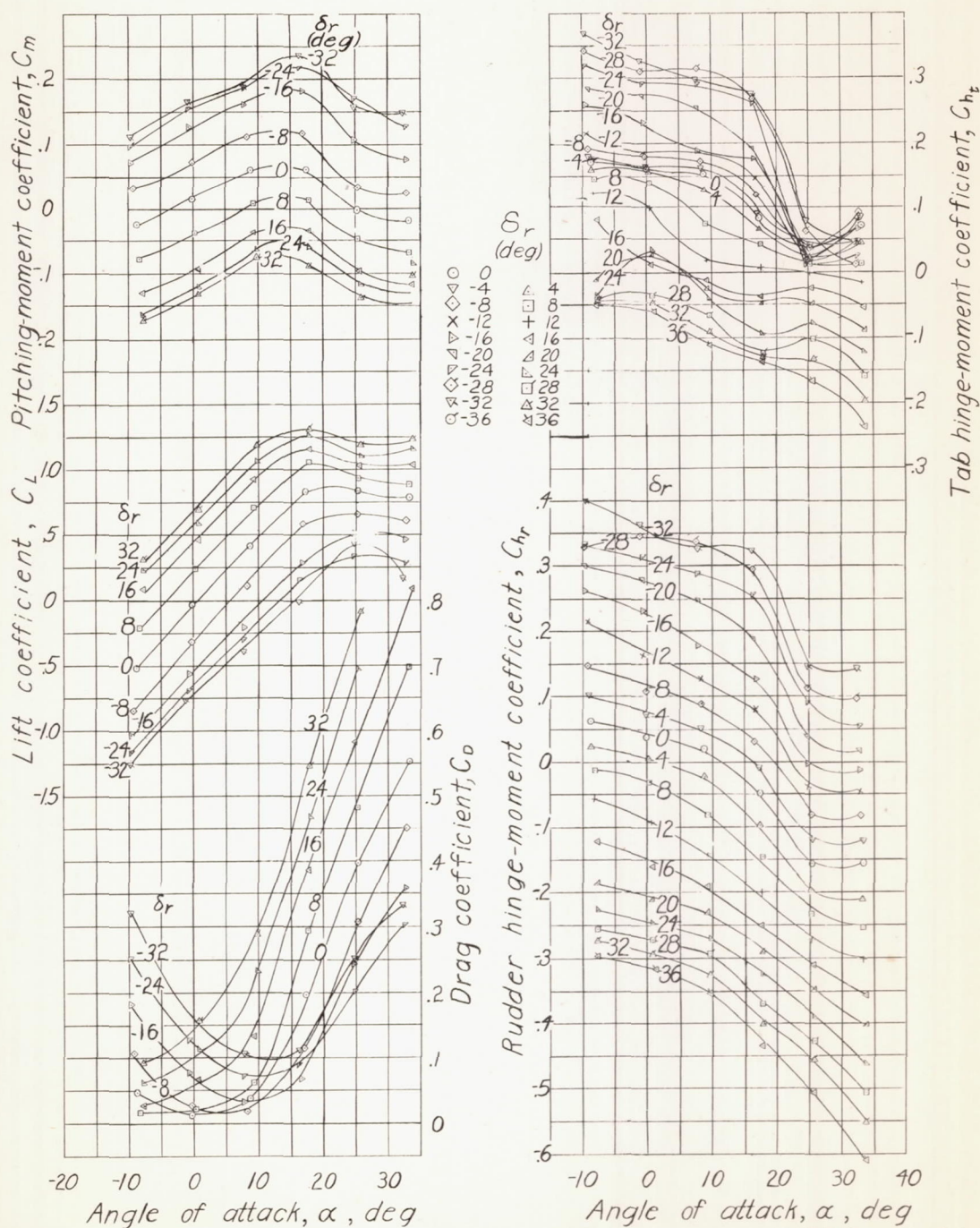
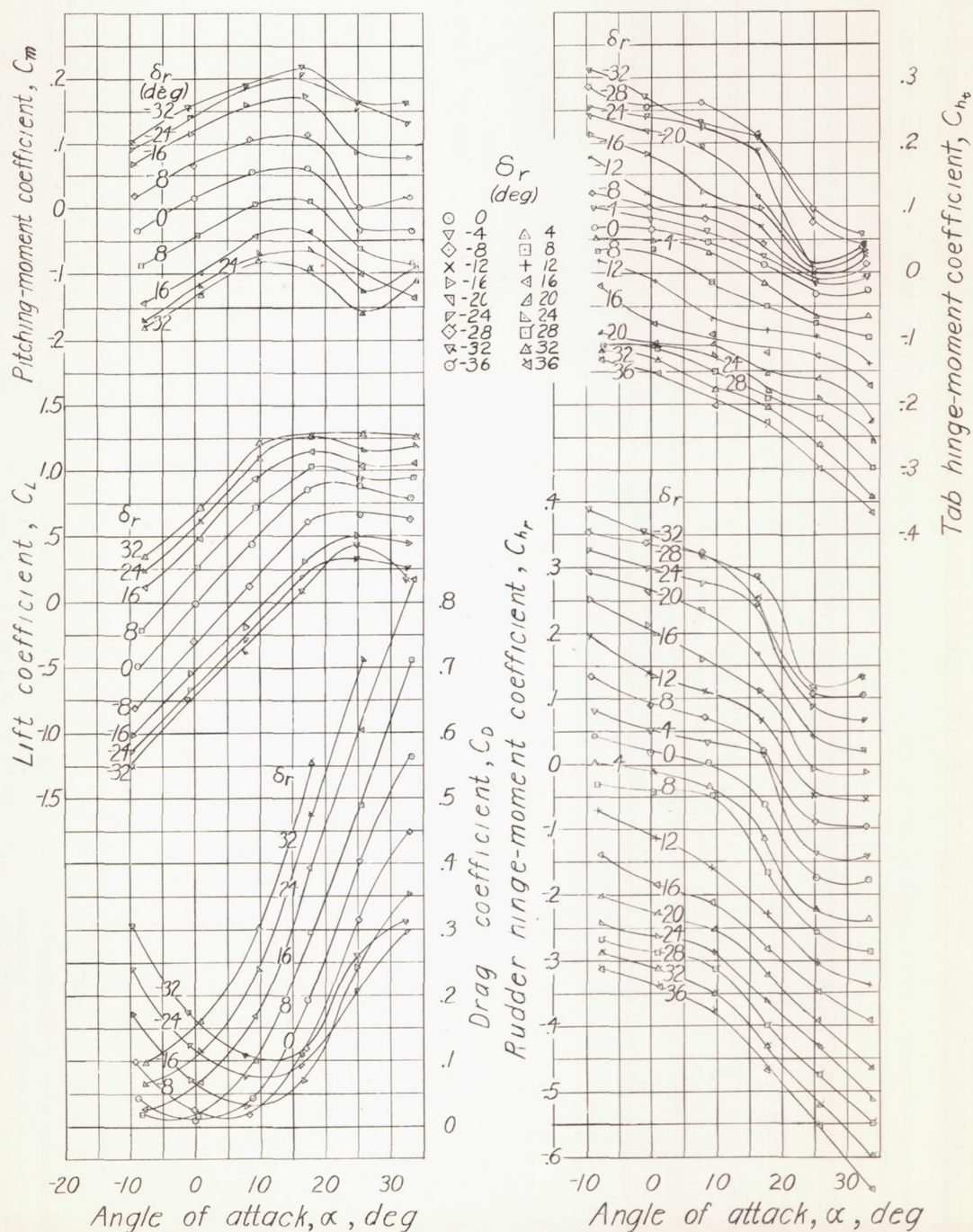


Figure 31.- Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface. Plain sealed rudder.

Original tab; $\delta_t = -20^\circ$.



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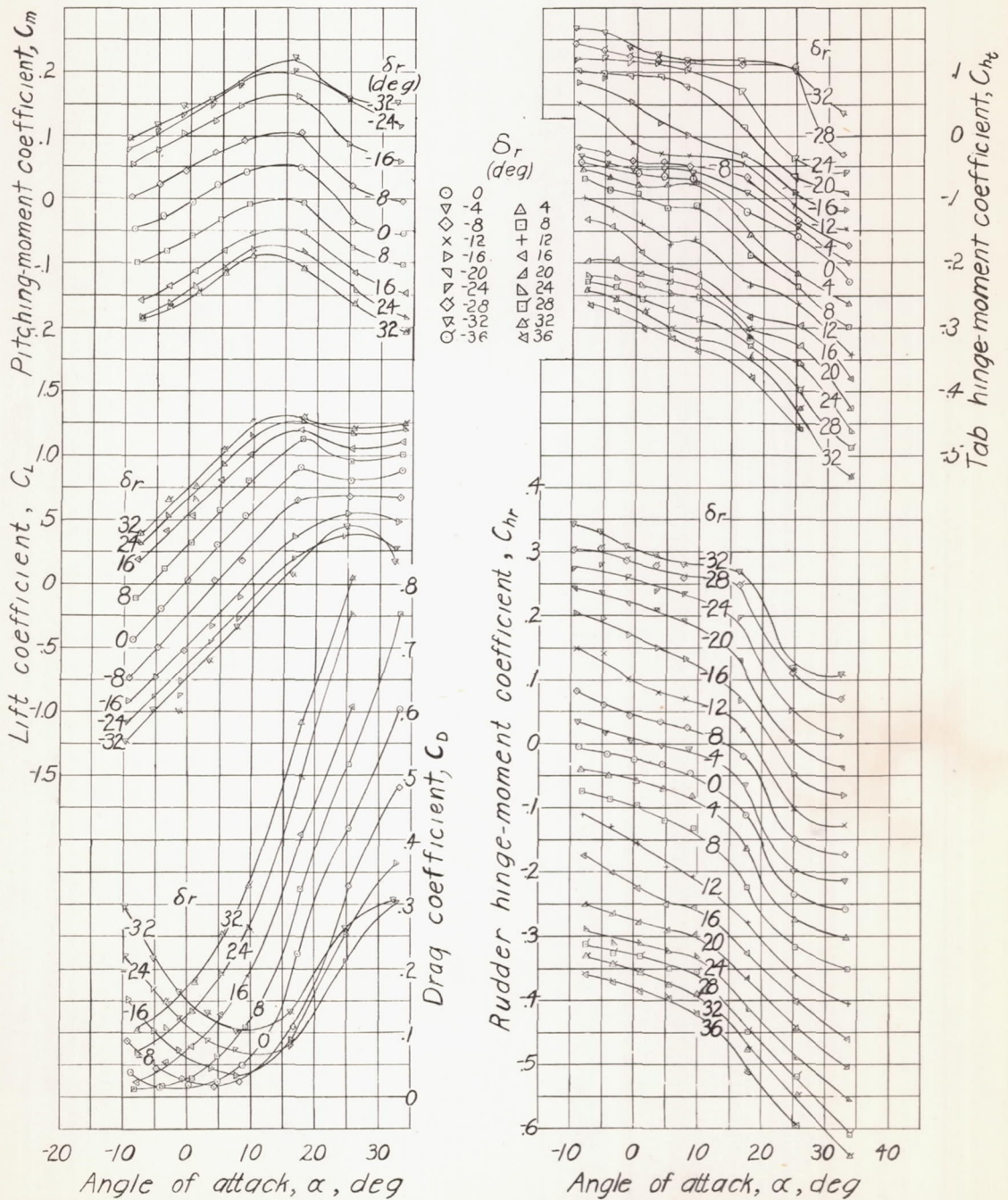


Figure 33.-Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface. Plain sealed rudder.

Original tab; $\delta_t = 10^\circ$.

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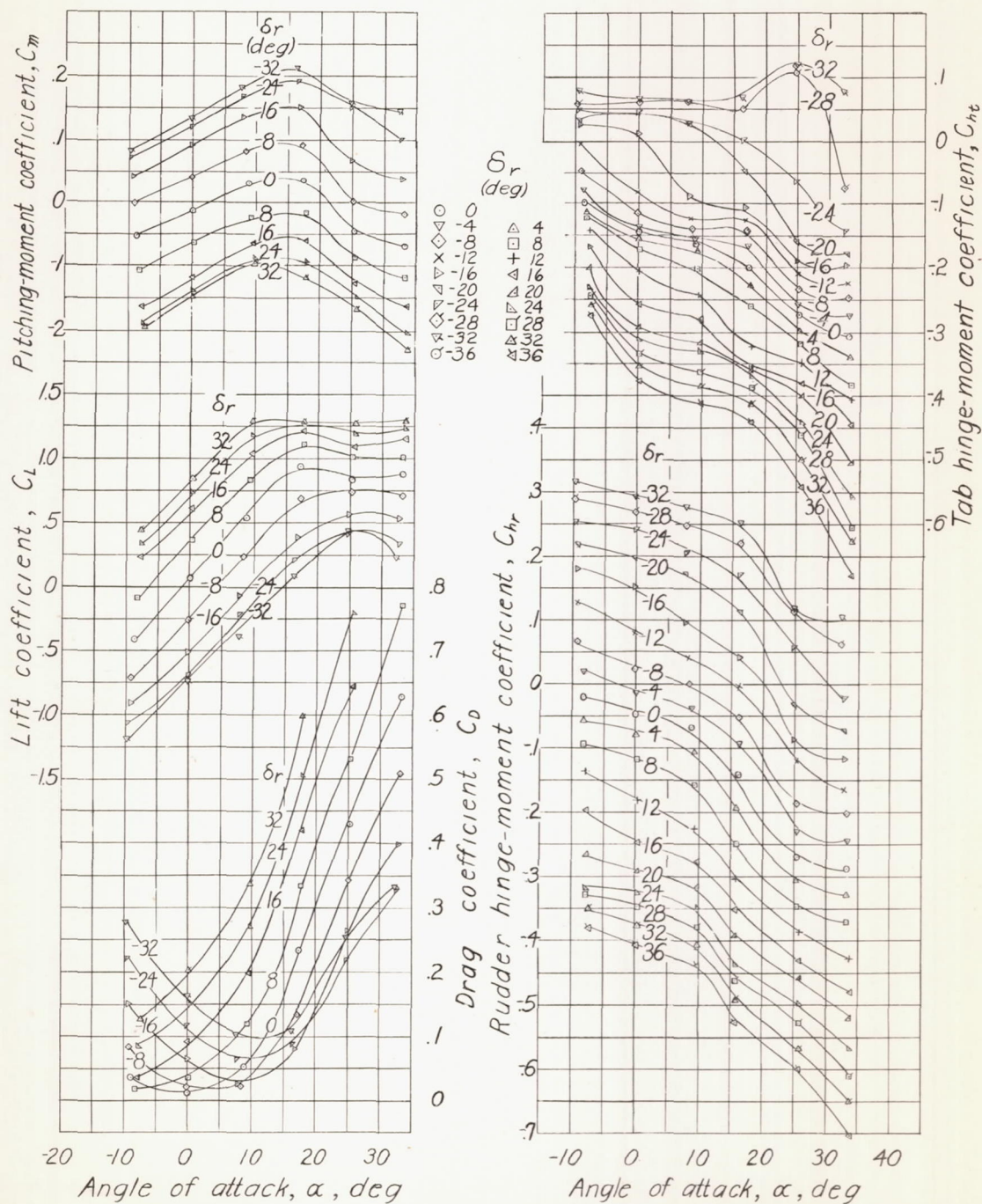


Figure 34.- Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface. Plain sealed rudder.

Original tab; $\delta_t = 20^\circ$

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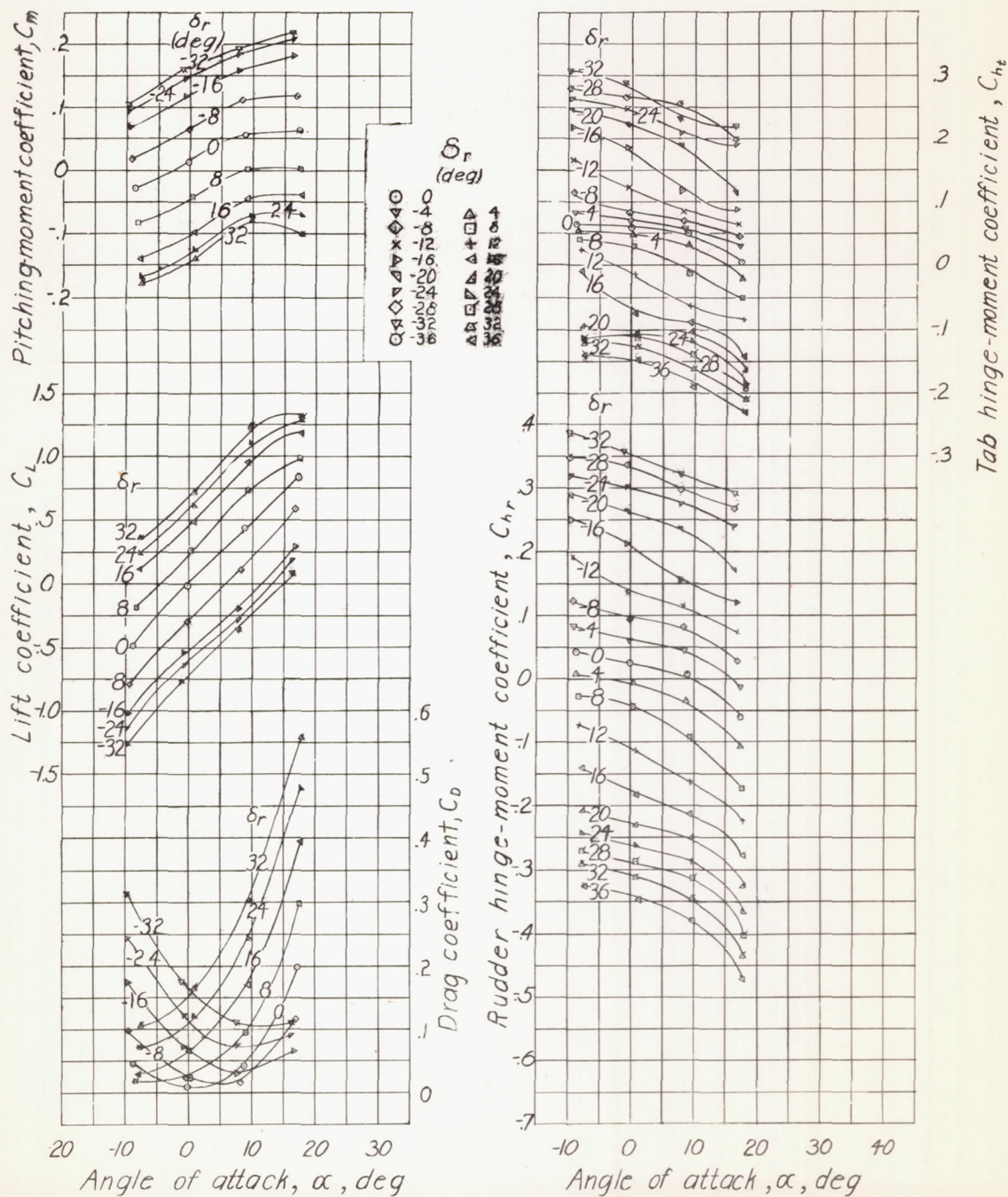


Figure 35.-Aerodynamic characteristics of Q7-scale model of XF6F vertical tail surface. Plain sealed rudder. Original tab sealed; $\delta_t = -10^\circ$.

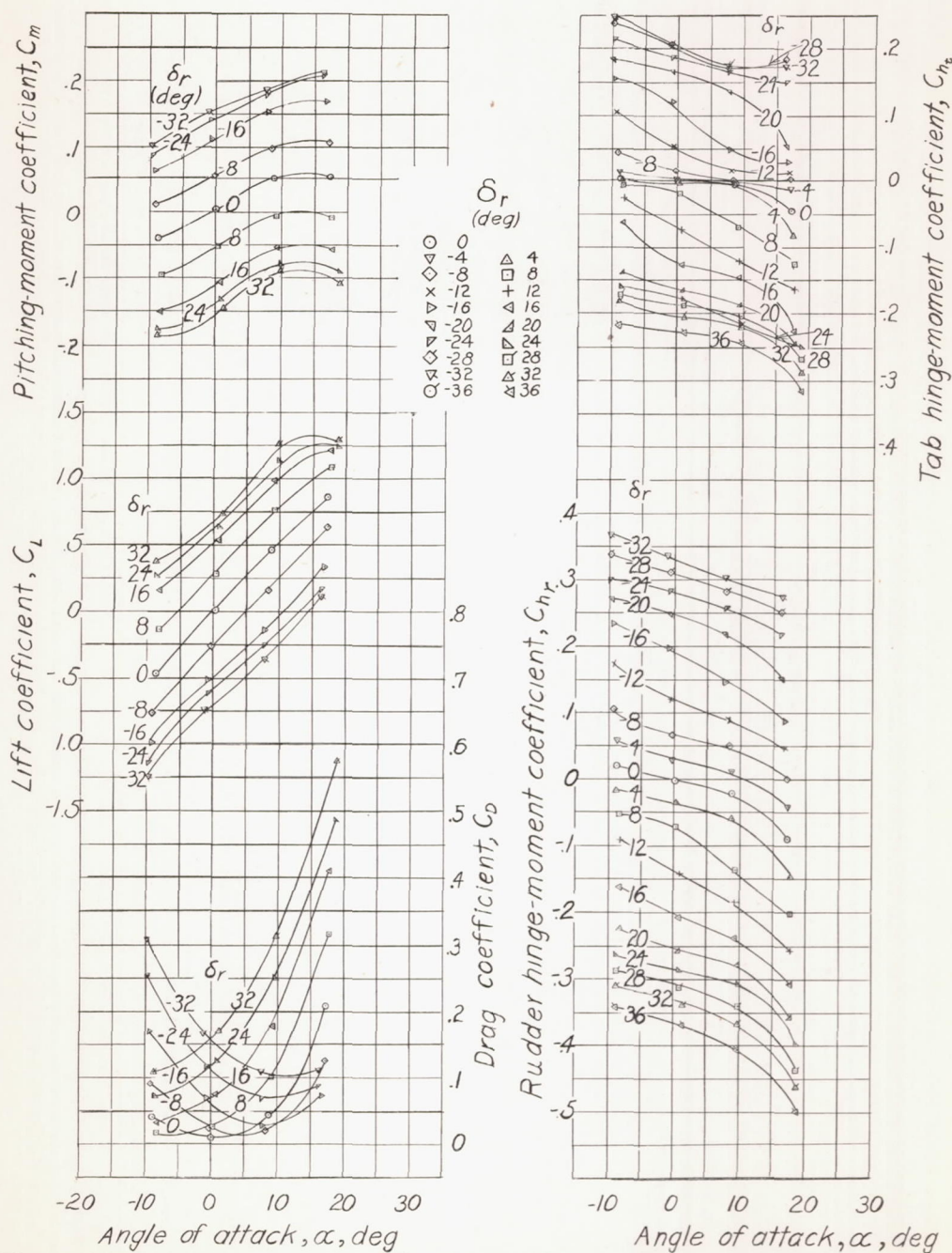
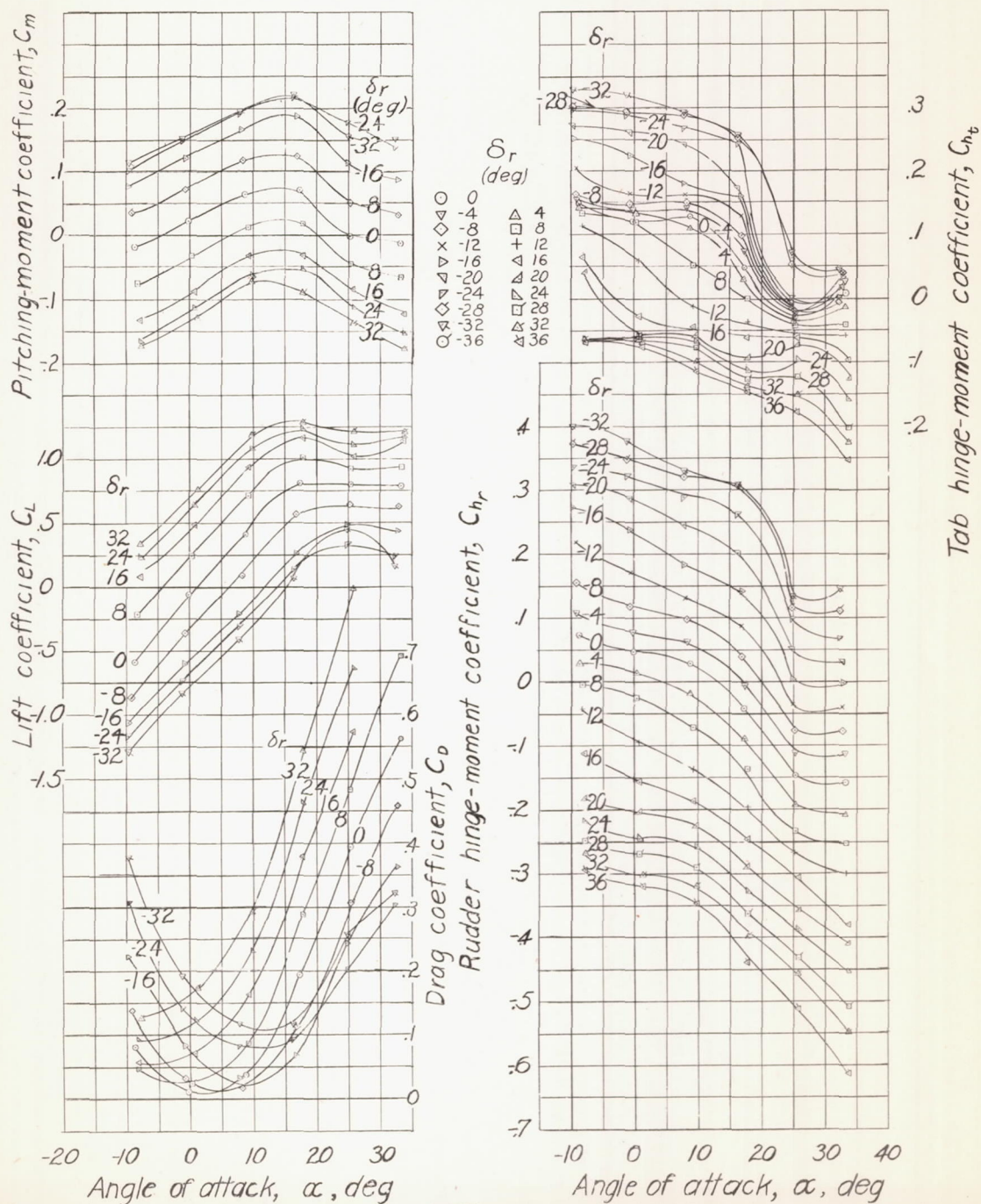


Figure 36.-Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface. Plain sealed rudder. Original tab scaled; $\delta_t = 0^\circ$.



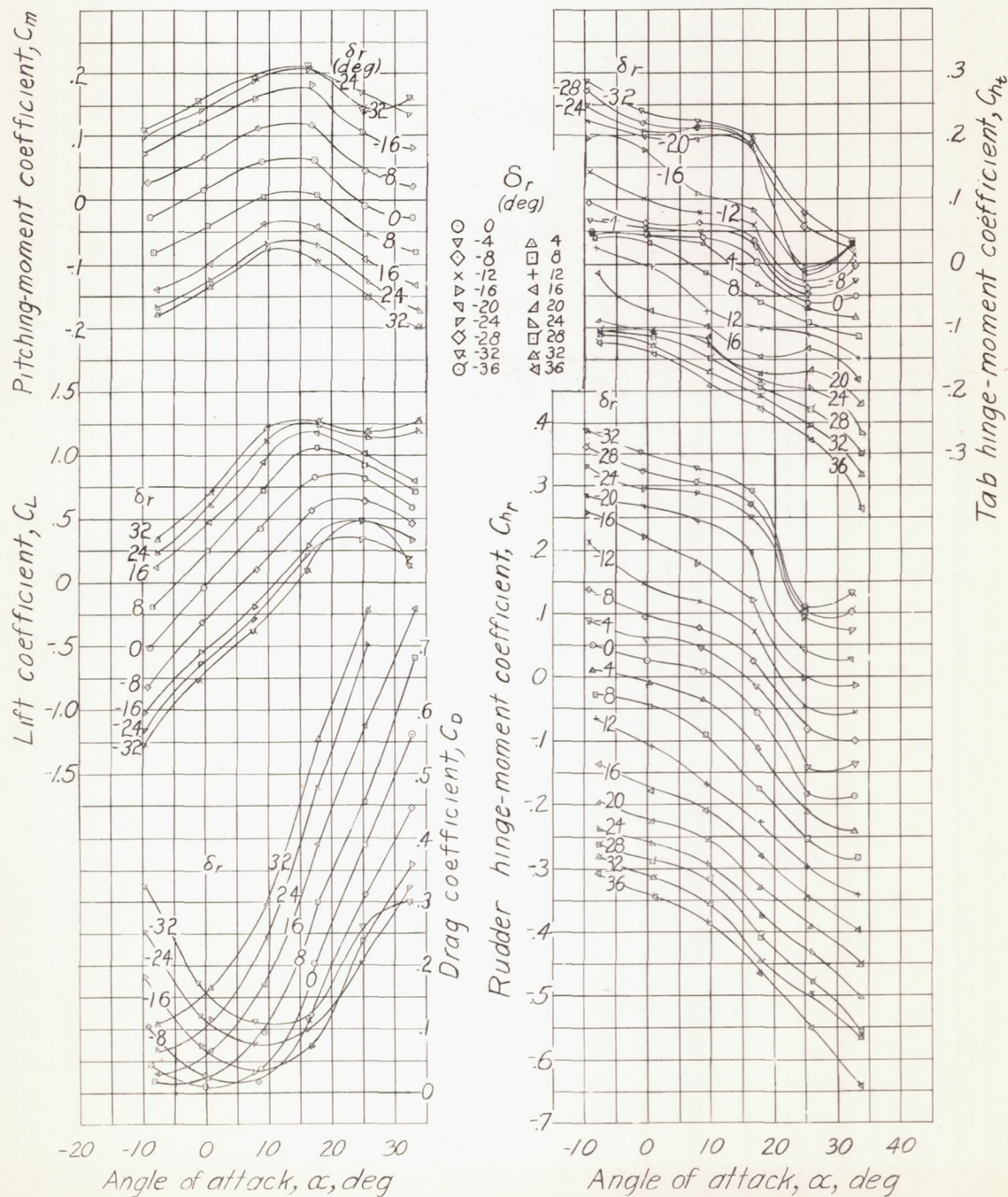


Figure 38. Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface. Plain sealed rudder. Round-nose tab; $\delta_t = -10^\circ$.

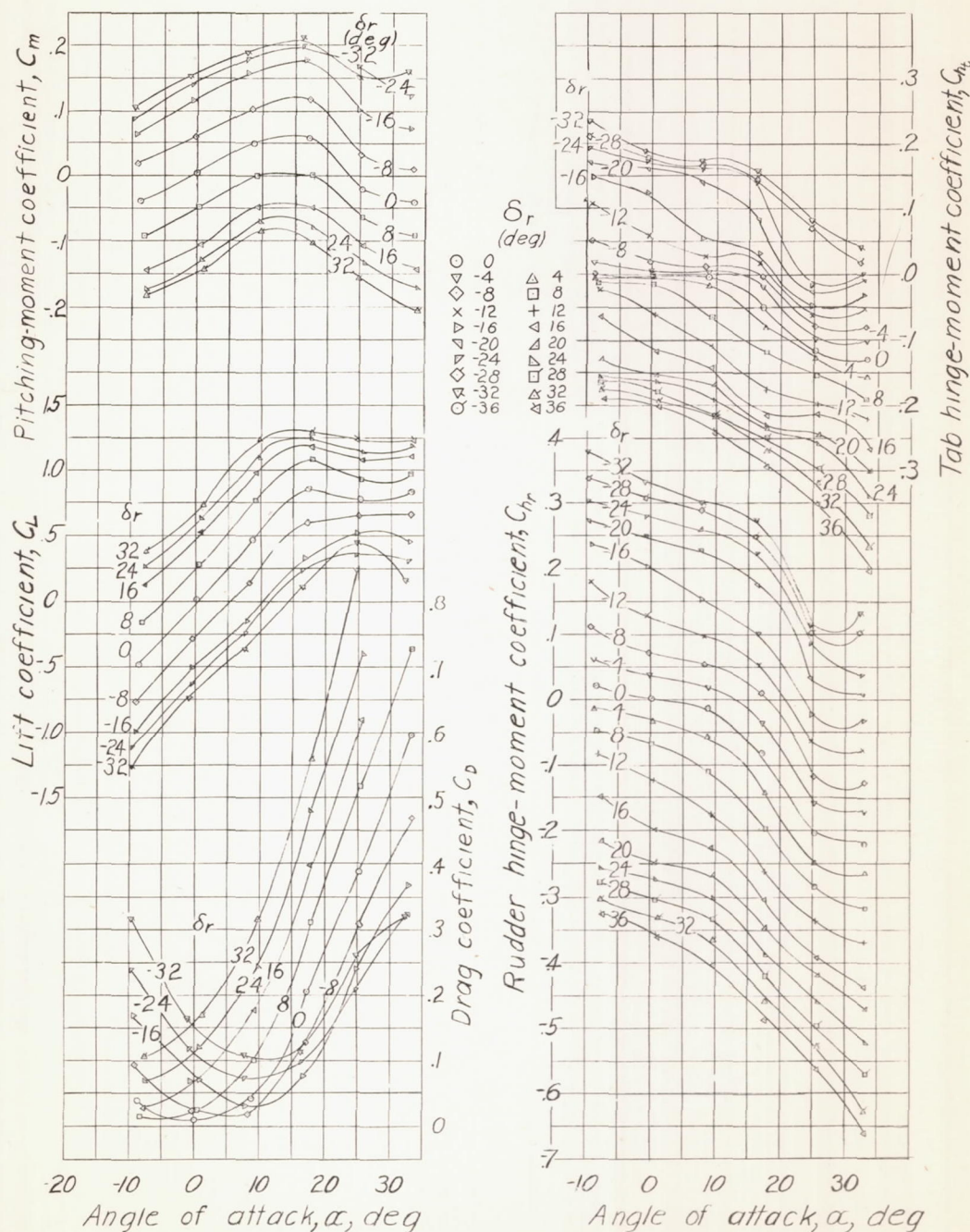


Figure 39.-Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface. Plain sealed rudder. Round-nosetab; $\delta_t = 0^\circ$.

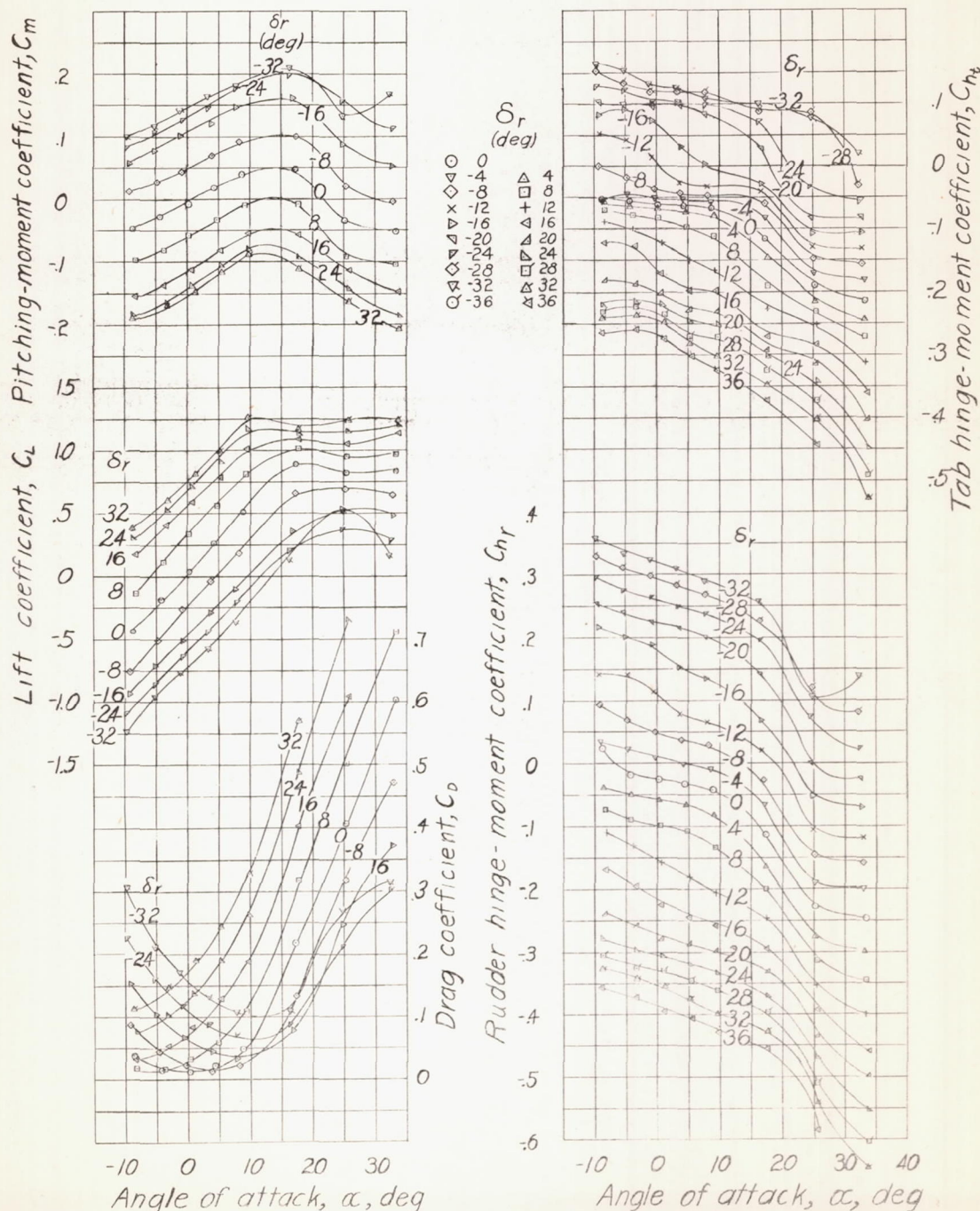


Figure 40.-Aerodynamic characteristics of 0.7-scale model of XF 6F vertical tail surface. Plain sealed rudder. Round-nose tab; $\delta_t = 10^\circ$.

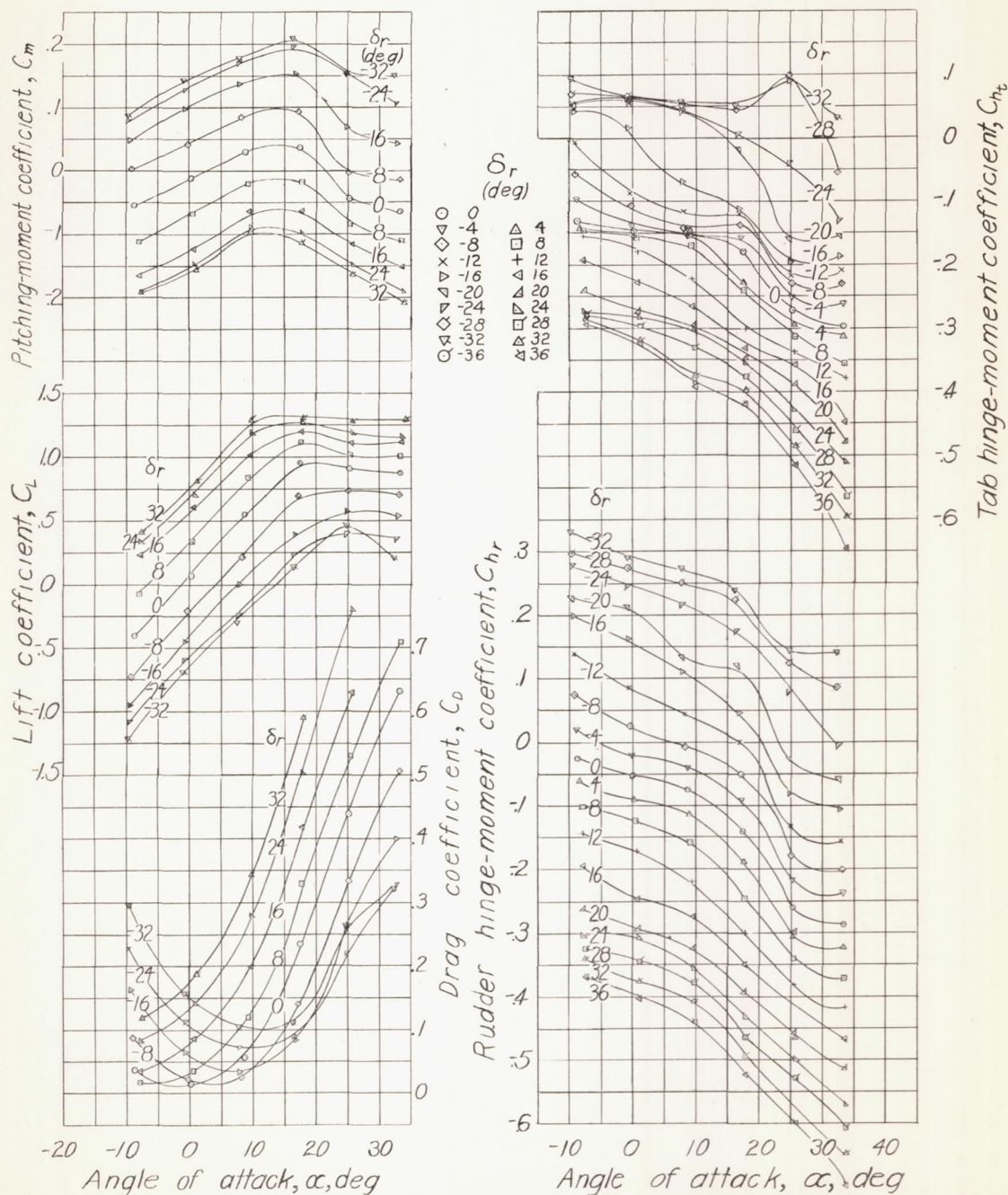
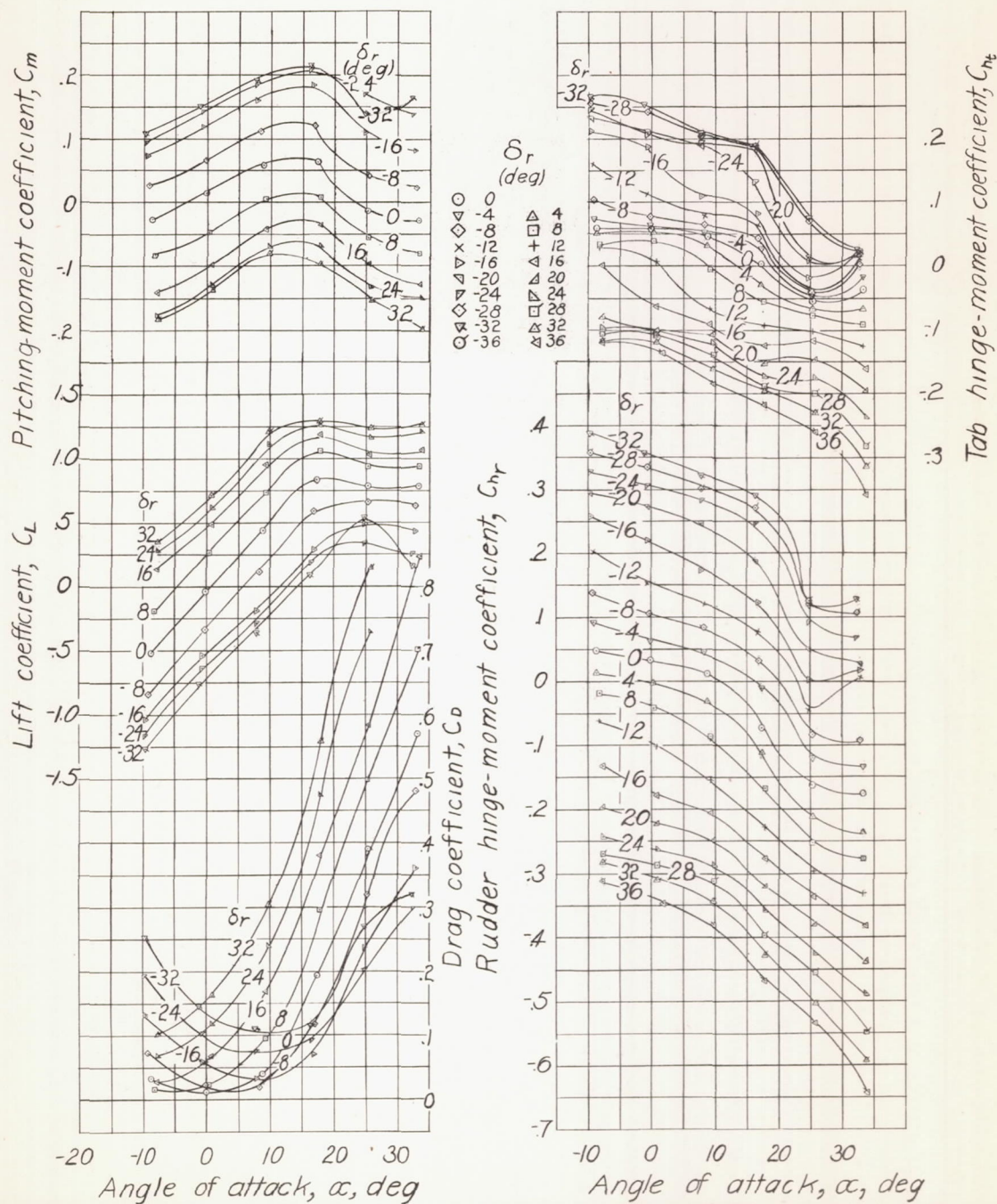


Figure 41: Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface. Plain sealed rudder. Round-nose tab; $\delta_t = 20^\circ$.



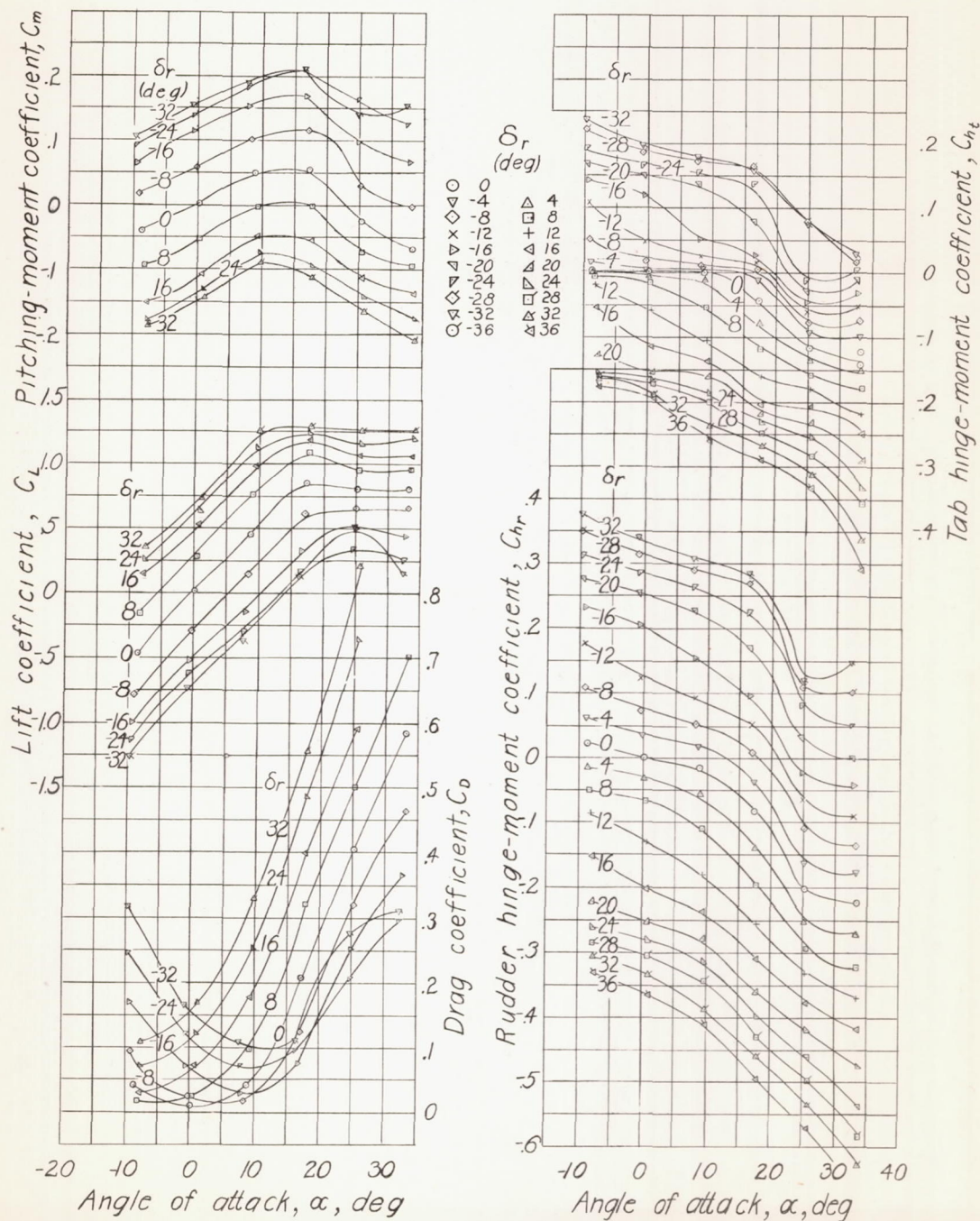


Figure 43.-Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface. Plain sealed rudder. Round-nose tab sealed; $\delta_t = 0^\circ$.

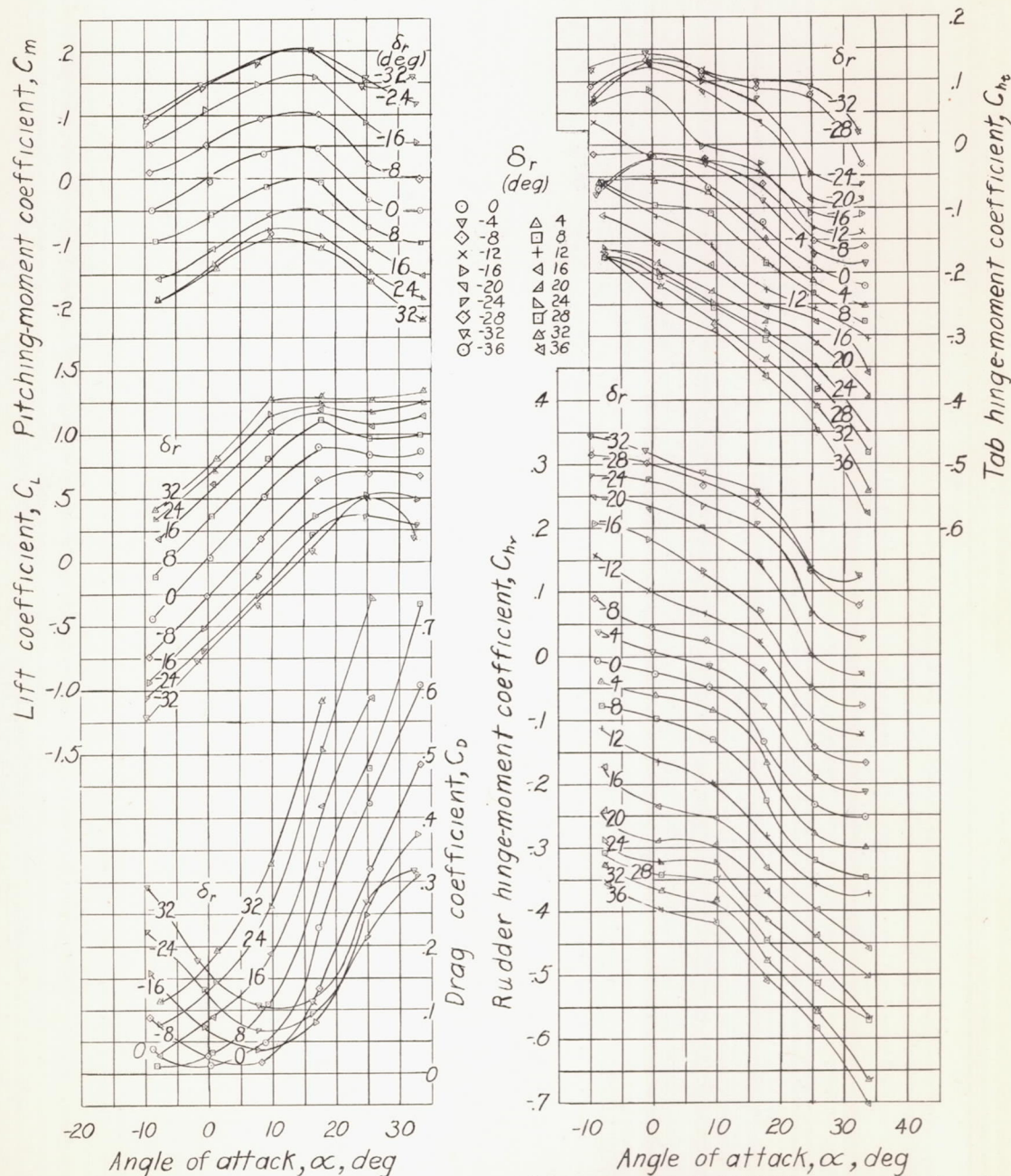


Figure 44.-Aerodynamic characteristics of 0.7-scale model of XF6F vertical tail surface. Plain sealed rudder. Round-nose tab sealed; $\delta_t = 10^\circ$